JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION

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Vol. 37 November 1945 No. 11

Summary of 1945 Pension and Retirement Legislation

Committee Report

Dale L. Maffitt, Chairman, A.W.W.A. Committee on Pensions and Retirement Plans

IN general, state legislators have shown an unusual interest in retirement and pension legislation during the past year. From the material available it appears that at least fifteen states have enacted new legislation to establish pension systems for state, city and county employees who have given long service. These states are: Florida, Georgia, Indiana, Iowa, Maine, Maryland, Michigan, Montana, Nebraska, North Carolina, Oregon, South Carolina, South Dakota, Utah and Wisconsin.

Several states—California, Massachusetts, Minnesota, New Jersey and New York—have passed laws amending their existing pension systems.

At least three states—Kansas, New Hampshire and North Dakota—attempted to pass retirement laws without success.

The legislatures of Louisiana and Mississippi are not in session in 1945. The legislature of Missouri continues in session until 1946.

1945 Legislation

Alabama. No report of legislation in 1945.

Arizona. No pension legislation in 1945.

Arkansas. No pension legislation in 1945.

California. Certain amendments to the California State Employees' Retirement Act were passed in the 1945 legislature. The text of the act as affected by amendments in 1945 will be compiled and published in due time, according to the supervisor of documents.

Colorado. No pension legislation in 1945.

Connecticut. No pension legislation in 1945.

Delaware. No information on pension legislation in 1945.

Florida. The 1945 legislature passed a law providing for retirement of state officials and state employees. There is a previously established retirement law for both county officials and employees.

Georgia. The City Council of Augusta passed a bill in the 1945 legislature providing a retirement system for city employees, which includes employees of the water department. The bill passed as House Bill No. 261, Act 173, but is a charter amendment for the city of Augusta only, and is not a state enactment.

Idaho. No pension legislation in 1945.

Illinois. No pension legislation in 1945. There is an established pension system for municipal employees.

Indiana. A law was passed establishing a state retirement fund. The bill also provides that local municipalities may take advantage of this, and it is believed that within a short time it will be arranged so that water works men can be placed under a retirement fund.

Iowa. Two bills relating to retirement systems, both of which affect water works employees, were passed in the 1945 legislature. One bill, known as Senate File No. 25, simply authorizes the city council or board of water works trustees to establish a pension and annuity retirement system for employees of water works systems in cities having a population of 5,000 or more. This bill became effective July 1, 1945. It provides that the pension and annuity retirement system can be created from proceeds of assessments on wages and salaries of employees, from the interest on any permanent fund which may be created by gifts, etc., or from moneys derived from the operation of water works available and appropriated for this purpose.

The second bill is an over-all coverage bill providing for the retirement of all state, county and city employees, including schools and utilities. This bill is patterned after the federal social security set-up, and it is understood that it is so designed that in case the federal government extends social security benefits to the state, county and city employees, the state can turn over its system to the federal government. Participation is compulsory for all covered employees, except that there is a provision in the general law that provides that any public body that already has a retirement system set up may be exempt from the general law. The general law does not go into effect until Jan. 1, 1946, and therefore, presumably, any water works might set up its own pension and retirement system prior to Jan. 1, 1946, under Senate File No. 25 above, and thus be exempt from the general law.

Kansas. No pension legislation in 1945. A bill for the retirement of general city employees passed the senate, but failed in the house on the last day of the session.

Kentucky. No pension legislation in 1945.

Louisiana. Legislature does not meet in 1945. Next session will be in 1946.

Maine. Several amendments to the Employees' Retirement System were approved in the 1945 legislative session. One was an act permitting employees of water districts and other quasi-municipal corporations to become members of the State Employees' Retirement System, providing the governing body of the city or the trustees of the water districts approve such participation.

Maryland. A bill, known as Senate Bill No. 432, was passed. This provides for the inclusion of employees of municipal corporations, including county, incorporated town or municipality or other political sub-divisions of the state, in the Employees' Retirement System of the State of Maryland. Under the terms of membership in the retirement system, employees of municipal corporations are included, subject to approval of the municipal corporations employing them. The bill becomes effective Jan. 1, 1947.

Massachusetts. The law on retirement systems has been revised in recent years, and according to Chester H. Grant, Executive Secretary of the Commonwealth of Massachusetts Board of Retirement, the Commonwealth of Massachusetts in 1945 enacted an entirely new retirement program.

Michigan. Senate Bill No. 315, approved May 3, 1945, is an act to provide for a municipal employees' retirement system; to create a municipal employees' retirement board and prescribe its powers and duties; to establish certain funds in connection therewith and to require contributions thereto by the participating municipalities and the municipal employees. *Municipality* means any county, city, village or township; any separate corporation or instrumentality established by a city or village as permitted by law; any corporation supported in the most part by counties, cities and villages, or any of them; and any public corporation charged by law with the performance of a governmental function and whose jurisdiction is co-extensive with a county, city or village. *Participating municipality* means any municipality which elects to have all or part of its employees covered by the retirement system.

Minnesota. Certain amendments to the existing Public Employees' Retirement Association Law were approved Mar. 12, 1945, as Law 1945, Chap. 78. These amendments bore on the date of retirement and membership upon leaving service.

Mississippi. Legislature not in session this year.

Missouri. Legislature continues in session until sometime in 1946. No pension legislation passed as of July 30, 1945.

Montana. Chapter 212 of the 1945 Session Laws of Montana was approved and became effective Mar. 16, 1945. This legislation is an act to provide for the creation, establishment and operation and also the adjustment with other existing systems, of a comprehensive retirement system for employees of the state of Montana and all employees of such cities and counties (except city policemen, city firemen and Montana state highway patrol), all within the state, as may elect to include their employees pursuant to contract with the board of administration of such system, to be known as the Public Employees' Retirement System, and making an appropriation therefor.

Nebraska. Legislative Bill No. 217, providing for the creation and operation of a retirement system for municipalities and municipal utilities, was approved May 10, 1945. The purpose of the system is to provide a sound and efficient means for the payment of annuities and other benefits to employees, and to beneficiaries of employees, of municipalities and utilities in the state. The system so created is to be known as the Nebraska Municipal Retirement System. Municipalities may elect to have one or more departments participate in the system, and election shall be by vote of a ma-

jority of the electors of such municipality voting at said election.

Nevada. No pension legislation in 1945.

New Hampshire. House Bill No. 200–201 proposed the establishment of a retirement system for municipal employees. A letter from the secretary of state dated July 30, 1945, states that no legislation relative to retirement systems for water works employees was passed in the 1945 session.

New Jersey. Senate Bill No. 176 was passed, being an amendment to the existing State Employees' Retirement System. The amendment had to do with prior service.

New Mexico. No pension legislation in 1945.

New York. A number of amendments to existing pension laws were presented in the 1945 legislature, for the purpose of altering the civil service law in relation to the state employees' retirement law. No information as to whether or not these amendments became law.

North Carolina. Legislation was adopted enabling municipalities and counties to participate in a state-wide retirement system for employees.

North Dakota. At the present time any city in North Dakota of over 4,000 population can adopt civil service. Those over 10,000 which have civil service can also adopt retirement plans. An attempt was made by the League of Municipalities to lower the population limit of cities permitted to adopt civil service. The original attempt was to permit all cities to adopt civil service. When this failed, an attempt was made to permit municipalities of over 4,000 to adopt retirement plans. Both attempts failed.

Ohio. There is a law which takes care of both municipal and state employees in a retirement system. No additional legislation was passed in 1945.

Oklahoma. No pension legislation in 1945.

Oregon. House Bill No. 344, effective July 1, 1945, establishes a system of retirement and of benefits at retirement or death for certain officers and employees of the state and its political subdivisions; provides for the integration of other similar systems with this system; and provides for the costs of the system, appropriating money therefor and providing a savings clause.

Pennsylvania. No information on 1945 pension legislation.

Rhode Island. No information on 1945 pension legislation.

South Carolina. A retirement act was passed by the 1945 General Assembly and is now being set up. Municipal water departments are eligible to participate in the retirement system.

South Dakota. Senate Bill No. 153 was approved Mar. 9, 1945, and provides for establishing a fund for the payment of pensions to retired officers and employees of municipalities, and provides for a levy therefor. Cities may prescribe by ordinance the class of employees and officers who shall receive the benefit of the pension fund.

Tennessee. No pension legislation in 1945.

Texas. No pension legislation in 1945.

Utah. Senate Bill No. 45 became a law May 8, 1945. This bill provides for retirement of appointive officers and employees of cities of the first class (50,000 or over) with pensions or retirement benefits and for payment of sickness, disability and death benefits.

Vermont. No pension legislation in 1945. There is a previous law under which a municipality having a popula-

tion of at least 5,000 may adopt a pension system for certain employees.

Virginia. No pension legislation in 1945.

Washington. No pension legislation in 1945. There is no state-wide retirement system in effect in the state, but certain cities have retirement systems established by ordinance.

West Virginia. No pension legislation in 1945.

Wisconsin. The 1945 legislature extended the provisions of the state municipal retirement system to include counties, school districts, sewerage districts and certain towns on an optional basis. At the present time, the system is operating with 43 cities and villages as participating municipalities. In each case the action to participate was taken by the governing body, namely the city council or the village board, and included all eligible employees, of which water works employees were a part if the water works was municipally owned. As of Aug. 3, 1945, certain cities, counties, school districts and sewerage districts have acted to participate as of Jan. 1, 1946, in addition to those now included.

Wyoming. No pension legislation in 1945.

Modern Rate Schedules

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A contribution to the Journal

MANY managers of municipal water departments and sewage disposal departments are now restive about their rate schedules. Investigation of the origins of such schedules for the furnishing of water and treatment of sewage and trade wastes reveals that most of them were hurriedly established by plagiarizing from rate tables in nearby cities or villages. Others have been developed by trial and error from an obscure beginning. In most cases a rate schedule which produces enough revenue to operate the system and pay interest and amortization on outstanding bonds is considered acceptable. In other instances the test of acceptability seems to hinge on customer acquiescence. In these latter situations a rate schedule which does not bring a flood of complaints to the billing office is usually deemed to be a thoroughly satisfactory method of charging for water supply and sewage disposal, and when complaints increase in volume and vigor, it seems advisable to adjust rates downward until a normal state of passive payments is achieved. Conversely, when complaints are noteworthy by their absence, elevation of unit charges is the order of the day. By such a delicate system of checks and balances rate-making is exceptionally free from emotionalism and mathematics.

In recent years, however, many water departments and sewage disposal departments have developed an urge to achieve a truly balanced budget, to follow good rate-making policies and to earn a fair return on net worth. Cash balances so obtained can be used for deficits in other city departments, if legally possible, for depreciation reserves; for increasing salaries; for necessary repairs, replacements and betterments; for testing, repairs to and replacements of meters and for new meter installations; for water waste surveys and leak elimination; for cleaning water mains and sewers; for improved treatment of water and sewage; for calling bonds and reducing interest charges; for installing new business machines for billing, calculating and bookkeeping; and, most important of all at present, for postwar planning and construction.

As is commonly known, the basis of any rational rate schedule should be an up-to-date inventory and appraisal of all real and personal property and operating capital. These documents should be prepared so that they can be easily revised periodically and harmonized with the books of account. A permanent inventory should be maintained and harmonized periodically with a co-ordinated appraisal or valuation. Such inventories need not ordinarily be of the "nut and bolt" variety. "Check" appraisals, prepared by engineers familiar with the types of construction involved, but more detailed

than the ordinary "horse-back" variety of such reports, will usually suffice for rate-making purposes in the case of municipal utilities.

A study of current federal income tax forms is useful in formulating policy for calculating annual fixed financial charges. Equally useful is the technical literature dealing with rate-making and the many decisions in rate cases promulgated in recent years by the courts and by public service commissions, and current War and Navy Department methods of cost analysis.

Many errors are made in comparing and establishing rate schedules by failing to take into account vital differences in physical property holdings. Some water departments own the water mains, others own none or only a portion of them, particularly if it is assumed that value of water pipe paid for by special assessment, or in some other manner directly by the property owners, is not properly a part of the rate base. Some water departments filter or soften water, while others do not. Wide variations are found in the per capita cost of water supply works. Some water distribution systems are adequately sized and valved for fire protection while others are not. Some sewage disposal plants achieve complete treatment; in many cases only primary treatment is provided. In some cases long expensive interceptors are used to convey sewage and trade wastes to the treatment plant; in others very little of such construction is involved. Some sewage disposal charges include financing of sanitary and/or relief sewers.

For defensible rate schedules it is essential that the fixed charges embodied in the rates be correctly related to a reliable present-day valuation of the property, real and personal, which is at the service of the rate payers. Only if this is done can rational readiness-to-serve charges be formulated.

In order to meet its fixed annual financial obligations a water department or a sewage treatment department needs regular sustained income in the form of readiness-to-serve or service charges from all of its customers all of the time. If a family goes to Florida for an indefinite time and closes up its house, fully expecting to return unannounced some night, tired and travel worn, and proceeds to take baths, it is reasonable to require that family not only to pay consumption charges for its pro rata share of chemicals, electric power, operating labor and other operating expenses required for processing all the water drawn through its plumbing fixtures, but also to pay regularly and continuously for the mere privilege of having the plumbing fixtures ready to operate.

Whether its customers stay home or go away, whether they use much water or little, a water department must be ready to operate every day in the year. And so readiness-to-serve charges are justifiable, in order that fixed financial charges which are inexorable can be met safely and surely.

It is the author's opinion that such a readiness-to-serve charge or service charge should not be concealed as a part of the minimum bill in a block rate schedule but should be clearly stated and charged for. In a recent report, which was made by the author's firm and which contained a valuation and rate study for a city of 50,000 population, it was recommended that fixed financial charges be covered by an integration of individual readiness-to-serve charges in addition to consump-

tion charges, with a system of dual rates as follows:

(1) Flat "service" or "readiness-to-serve" charges calculated to yield the total of the fixed financial expenses justifiably chargeable to the customer.

(2) "Consumption" charges calculated to yield the total of the operating expenses.

The recommended "readiness-to-serve" charges were based on the size of the meters serving the customers, assuming that the larger the meter the larger the part of required plant needed to serve the consumer adequately.

In establishing the rate base for the above system of "service" rates, all monies expended for the construction of any portion of the water system were included, except where improvements, extensions or additions were financed by special assessments; but if property owners were rebated for special assessments, all monies so rebated were also included in the rate base. For the purpose of that report, it was explained to the municipality that all special assessment monies had been rebated, with the exception of $65,315, which was deducted from present worth in arriving at net worth. The outstanding funded debt of the water department as of Jan. 1, 1945, amounted to $338,000. This amount was deducted from present worth in arriving at net worth.

In arriving at the present worth of the water system, reproduction costs, based on 10-year average prices and depreciated on a straight-line basis, were used. Annual depreciation charges were calculated by estimating the total useful life of the structure, equipment or other units and computing the expended life up to Jan. 1, 1945.

The fixed financial charges involved in calculating the readiness-to-serve charges were as follows:

(1) Interest on funded debt for the year of 1945 amounting to $11,328.

(2) Depreciation expense based on the weighted average remaining useful life of the existing water plant, and the present worth. The present worth was found to amount to $2,564,838, and the average remaining useful life is 57.15 years. By dividing the present worth by 57.15 years, it was found that the annual depreciation charge would be approximately $45,000.

(3) Real estate and personal property taxes were computed on the 1944 total tax rate of $21.95 per thousand. The valuation of both personal and real property for tax purposes was taken at 60 per cent of the total present worth.

(4) The water department recently has paid into the general fund a franchise fee of $10,000 per year, which is the water department's pro-rated share of the general expense of the city.

(5) An amount of $3,000 was allowed for casualty losses. This amount of money could be used for the payment of premiums on "all-risk casualty insurance," or the water department could establish a sinking fund to pay for any casualties that may occur which are not covered by insurance.

(6) Rate of return has been taken at 5½ per cent of the net worth of the water system. In arriving at the net worth, the total bonded debt as of Jan. 1, 1945, amounting to $338,000, and the unrebated amount of special assessments, $65,315, were deducted from the present worth. An allowance for working capital of $40,000 was made as an element in net worth.

(7) A fire hydrant rental charge of $40 per hydrant on 1,158 hydrants, or $46,320, was deducted from the sum of the above fixed expenses in arriving at the net amount. As is stated in an

article entitled "A Rational Method of Analyzing Water Rate Structures" by S. R. Wright, "Municipal government should pay to the water company a just fee for fire protection service from the general fund, and in turn taxes should be paid by the water company into the general fund."

The readiness-to-serve charge for a ⅝-in. meter was then calculated by dividing the net fixed expenses by the total number of "equivalent ⅝-in. meters" in service on Dec. 31, 1944. The number of equivalent ⅝-in. meters was calculated by equating the various size meters to ⅝-in. meters in accordance with a capacity factor.

A summary of the calculation involved in arriving at the readiness-to-serve charges for the various size meters is shown in Table 1.

This resulted in a forecast of income from readiness-to-serve charges as shown in Table 2.

The recommended maximum readiness-to-serve charges included all fixed financial expenses and a rate of return of 5½ per cent on net worth. In addi-

TABLE 1

Determination of Readiness-to-Serve Charge

Net Worth		
Total present worth		$2,564,838
Operating capital		40,000
		$2,604,838
Less bonded debt	$338,000	
Less unrebated amount of special assessments	65,315	403,315
NET WORTH		$2,201,523
Fixed Charges—1945		
Interest on funded debt		$ 11,328
Depreciation charge—$2,564,838 ÷ 57.15 =		45,000
Franchise charge		10,000
Equivalent real estate and personal property tax—$2,564,838 × 0.60 × .02195 =		33,780
Return on net worth (5½ per cent)—$2,201,523 × .055 =		121,083
Estimated casualty losses		3,000
Total Fixed Charges		$ 224,191
Deduct for fire hydrant rentals properly chargeable to the city's General Fund —1,158 hydrants @ $40.00 per year		46,320
ANNUAL NET FIXED CHARGES		$ 177,871

Readiness-to-Serve Charge for ⅝-in. Meter

$$= \frac{\text{Net Fixed Charges (above)}}{\text{Total Number Equivalent ⅝-in. Meters}}$$

Scheme 1—With 5½ Per Cent Rate of Return—All Other Fixed Charges

$$\text{Readiness-to-Serve Charge } \tfrac{5}{8}\text{-in. Meter} = \frac{\$177{,}871}{12{,}689} = \$14.02 \text{ per year.}$$

Scheme 2—With 0 Per Cent Rate of Return—All Other Fixed Charges

$$\text{Readiness-to-Serve Charge } \tfrac{5}{8}\text{-in. Meter} = \frac{\$56{,}788}{12{,}689} = \$4.48 \text{ per year.}$$

TABLE 2

Determination of Estimated Income Readiness-to-Serve Charges

(1) Size Meter *in.*	(2) No. of Meters	(3) Capacity Factor (Approx.)	(4) Equivalent No. ¾-in. Meters (2) × (3)	Scheme 1 Using Full 5½% Rate of Return		Scheme 2 Using 0% Rate of Return, Including All Other Fixed Charges	
				(5) Charge per Quarter	(6) Estimated Income (2) × (5) × (4)	(7) Charge per Quarter	(8) Estimated Income (2) × (7) × (4)
⅝	10,635	1.0	10,635	$ 3.50	$148,890	$ 1.20	$51,048
¾	171	1.3	222	4.50	3,078	1.50	1,026
1	92	1.8	166	6.50	2,392	2.00	736
1¼	26	2.6	68	9.00	936	3.00	312
1½	33	3.3	109	11.50	1,518	4.00	528
2	125	4.7	588	16.50	8,250	6.00	3,000
3	22	8.8	194	31.00	2,728	10.00	880
4	17	13.5	230	47.00	3,196	16.00	1,088
6	6	24.7	148	86.50	2,076	30.00	720
8	10	29.4	294	100.00	4,000	35.00	1,400
10	1	35.3	35	125.00	500	40.00	160
12	0	40.0	0	140.00	0	50.00	0
TOTAL	11,138		12,689		$177,564		$60,898

tion to this, computations were shown in Table 2 for alternate readiness-to-serve charges, which included all other fixed financial expenses but excluded any rate of return on net worth.

It was recommended that in addition to readiness-to-serve charges there be levied consumption charges calculated to yield the total of operating expenses only as shown in Table 3.

Similar readiness-to-serve and consumption rates were developed for the sewage disposal department in that city. In the proposed rate schedules for both water and sewage disposal departments it was found that much higher rates than the established rates could be justified. This was welcome news to a group of harassed city officials seeking new sources of municipal revenue.

Observations in a number of cities where similar dual rate schedules, incorporating a summation of readiness-to-serve charges and consumption charges, have been inaugurated in place of a conventional block rate, indicate a marked increase in income and very little customer dissatisfaction.

In the preparation of a modern rate schedule for either water supplied or sewage treatment rendered there should be studies made and variations incorporated in the billing to insure the reasonableness of the rates charged and at the same time to encourage the use of the service offered to the public.

It is impossible to develop formulas for such charges that will apply logically to all water and sewage disposal departments. There is much variation and there can be uniformity only in certain general principles.

If a utility department is to expand its sales and gain the benefit of resulting economies in operation, large

TABLE 3

Determination of Consumption Rates and Estimated Income Therefrom

Block No.	Block Limits in 100 cu.ft.	No. of Quarters in Block	Total Consumption in 100 cu.ft.	Average Consumption in 100 cu.ft. per Quarter	Rate per 100 cu.ft.	Average Charge per Quarter	Estimated Income
1	First 50	39,580	691,702	17.5	$0.14	$ 2.45	$ 96,971
2	Next 450	3,854	360,723	95.3	0.12	12.44	47,944
3	Next 500	68	46,720	687.1	0.10	79.71	5,420
4	Next 500	28	35,645	1273.0	0.08	132.84	3,720
5	Over 1,500	112	1,096,831	9793.1	0.06	648.59	72,642
	TOTAL	43,642	2,231,621				$226,697

customers must be given lower total gallonage rates than small ones. Otherwise large customers will be lost. A promotional rate to increase consumption can be developed in harmony with the principle of the dual rate herein advocated. The details of such a rate should be based on careful studies of the characteristics of the demands by existing and potential large customers. Low industrial rates are an inducement to industries seeking new locations, and the location of such industries may prove to be of great benefit to a large group of higher rate domestic customers. However, any industrial rate should be set only after thorough consideration of such elements as maximum rate of demand, variations in hourly and seasonal demand, character of trade wastes in case of sewage and trade waste disposal, cost of supply lines, and other elements in the situation that might lead to discrimination in favor of one class of customers. Once a special or discriminatory rate is allowed, succeeding requests for which precedent has been established will be numerous, and also new precedents will be sought after. Charitable institutions, schools and other eleemosynary institutions are seldom accorded special rates for electric light and power or gas, but usually feel that they should have very special treatment when it comes to billing for water supply or sewage disposal.

Needless to say, any revision of existing rates requires careful education of the public and well-written publicity setting forth the results of an engineering analysis of the valuation, fixed charges, operating expenses and anticipated income under the new rates. When such an explanation is undertaken the qualifications and experience of the rate makers should be emphasized and comparisons with similar rates elsewhere should be offered.

Customers outside the corporate limits need to be studied with great care and the influence of their activities on community affairs must be appraised before rates for them are established. Certainly in the absence of extenuating circumstances, such consumers should be required to pay both a proper readiness-to-serve charge, including a contribution towards fair rate of return on value of utility property plus a correct consumption charge. It seems fair that such rates should include the element of fair rate of return

on invested capital even if rates for customers within the corporate limits do not reflect that item of cost.

Proper rate-making for water and sewage disposal departments will affect almost every rate payer every day and so it is of utmost importance that a proper foundation be laid for revision of rates by preparing a good inventory and valuation and by proper rate-making studies, analyses and conclusions. A municipality's over-all finances are vitally affected by the type of rate-making utilized and from that standpoint, too, careful engineering analysis and rate design are essential.

Water Rates in Some Typical Cities

By John A. Fulkman

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TABLE 1

WATER SUPPLY DATA

KEY TABULATION, POPULATION AND TYPE OF TREATMENT FOR VARIOUS CITIES

A Lake Michigan Supplies—Filtered			B Lake Michigan Supplies—Not Filtered		
No.	City	Population	No.	City	Population
1	Grand Rapids, Mich.	164,300	12	Gary, Ind.	111,700
2	Hammond, Ind.	70,200	13	Traverse City, Mich.	14,500
3	Evanston, Ill.	64,500	14	Ludington, Mich.	8,700
4	Kenosha, Wis.	48,800	15	Port Washington, Wis.	4,000
5	Muskegon, Mich.	47,700	16	Cudahy Water Co. (Wholesale)	10,600
6	Sheboygan, Wis.	40,600			
7	Waukegan, Ill.	34,200			
8	Michigan City, Ind.	26,500			
9	South Milwaukee, Wis.	11,100			
10	Whiting, Ind.	10,300			
11	St. Joseph, Mich.	9,000			

C River (Surface) Supplies—Filtered and Softened				D River (Surface) Supplies—Filtered Only		
No.	City	Population	Type*	No.	City	Population
17	Fort Wayne, Ind.	118,400	LSA	25	E. St. Louis, Ill.	75,600
18	Springfield, Ill.	75,500	LSA	26	Davenport, Iowa	66,000
19	Cedar Rapids, Iowa	62,100	LSA	27	Rock Island, Ill.	42,800
20	Decatur, Ill.	59,300	LSA	28	Alton, Ill.	31,300
21	Quincy, Ill.	40,500	LSA	29	Burlington, Iowa	25,800
22	Bloomington, Ill.	32,900	LSA			
23	Ottumwa, Iowa	31,600	LSA			
24	Kankakee, Ill.	22,200	LSA			

TABLE 1 (contd.)

E Well Supplies—Softened				F Well Supplies—Not Softened		
No.	City	Population	Type*	No.	City	Population
30	Elgin, Ill.	38,300	LSA	35	South Bend, Ind.	101,300
31	Maywood, Ill.	26,600	Z	36	Rockford, Ill.	84,600
32	Marshalltown, Iowa	19,200	LSA	37	Aurora, Ill.	47,200
33	Benton Harbor, Mich.	16,700	LSA	38	Dubuque, Iowa	43,900
34	LaGrange, Ill.	10,500	LZ	39	Marion, Ind.	26,800
				40	Chicago Heights, Ill.	22,500
				41	Freeport, Ill.	22,400
				42	Mt. Pleasant, Mich.	8,400

*NOTE: L = Lime.
SA = Soda Ash.
Z = Zeolite.

TABLE 2

WATER RATES OF VARIOUS CITIES—AVERAGED BY SOURCE AND TYPE OF TREATMENT

1A—Lake Michigan Supplies—Filtered

		Rate in Cents per 1,000 Gal. at Quantities Given							
	Gal. per Month:	3,000	10,000	30,000	100,000	1,000,000	3,000,000	10,000,000	30,000,000
No.	City								
1 d	Grand Rapids, Mich.	25.2	18.0	13.5	12.0	10.0	9.3	8.9	8.9
2 e	Hammond, Ind.	33.3	10.0	10.0	9.3	7.0	5.7	5.2	5.1
3 c	Evanston, Ill.	24.3	18.5	16.4	13.3	9.8	9.5	9.4	9.3
4 d	Kenosha, Wis.	18.7	14.0	11.1	9.9	7.2	6.5	6.1	6.1
5 b	Muskegon, Mich.	25.0	16.0	16.0	16.0	10.0	8.0	8.0	8.0
6 c	Sheboygan, Wis.	21.3	17.6	13.1	10.5	7.2	5.7	5.0	4.8
7 d	Waukegan, Ill.	30.0	28.7	27.2	22.2	13.0	12.3	12.1	12.0
8 d	Michigan City, Ind.	25.0	9.8	9.3	8.2	5.6	5.0	4.8	4.7
9 d	South Milwaukee, Wis.	22.3	21.0	17.7	13.5	10.0	8.7	8.2	8.1
10 a	Whiting, Ind.	36.7	24.9	22.6	17.1	9.1	6.7	5.9	5.6
11 b	St. Joseph, Mich.	32.7	30.3	23.5	17.3	9.3	8.4	8.1	8.0
	AVERAGE	26.8	19.0	16.4	13.6	8.9	7.8	7.4	7.3
	1B—Lake Michigan Supplies—Not Filtered								
12 b	Gary, Ind.	25.0	25.0	20.0	13.0	6.9	6.3	6.1	6.0
13 b	Traverse City, Mich.	24.4	11.1	10.0	8.4	5.7	5.2	5.0	5.0
14 c	Ludington, Mich.	19.4	11.2	9.2	7.4	6.8	6.7	6.7	6.7
15 a	Port Washington, Wis.	20.0	18.3	16.8	15.6	9.8	8.6	8.2	8.1
16 d	Cudahy Water Co. (Wholesale)	8.1	8.1	8.1	8.1	8.1	8.1	7.8	6.1
	AVERAGE	19.4	14.7	12.8	10.5	7.5	7.0	6.7	6.4

TABLE 2 (contd.)

1C—River (Surface) Supplies—Filtered and Softened

No.	City	Rate in Cents per 1,000 Gal. at Quantities Given							
	Gal. per Month:	3,000	10,000	30,000	100,000	1,000,000	3,000,000	10,000,000	30,000,000
17 c	Ft. Wayne, Ind.	33.3	20.0	17.3	13.6	9.3	8.9	8.7	8.7
18 c	Springfield, Ill.	23.3	23.3	21.6	16.8	10.3	9.7	9.4	9.4
19 d	Cedar Rapids, Iowa	26.3	22.3	19.4	14.8	8.8	7.4	6.9	6.8
20 d	Decatur, Ill.	37.6	29.2	26.4	22.0	10.5	8.6	7.6	6.6
21 b	Quincy, Ill.	50.0	40.1	30.0	21.8	9.1	6.9	6.2	5.9
22 a	Bloomington, Ill.	64.8	61.3	51.8	42.2	19.9	17.4	16.6	16.3
23 b	Ottumwa, Iowa	25.0	25.0	25.0	19.0	11.6	9.9	8.0	7.0
24 b	Kankakee, Ill.	53.3	48.0	45.0	33.8	13.1	9.4	7.7	7.2
	AVERAGE	39.2	33.65	29.6	23.0	11.3	9.8	8.9	8.5
	1D—River (Surface) Supplies—Filtered								
25 c	E. St. Louis, Ill.	41.7	40.0	40.0	39.8	23.2	13.3	9.8	7.5
26 c	Davenport, Iowa	35.0	35.0	29.8	18.7	14.5	9.5	7.7	7.2
27 b	Rock Island, Ill.	23.3	18.7	18.2	14.7	8.7	8.2	8.1	8.0
28 d	Alton, Ill.	34.0	34.0	32.2	27.2	11.8	9.3	8.4	8.1
29 c	Burlington, Iowa	33.3	30.0	25.0	15.3	10.5	10.1	10.1	10.0
	AVERAGE	33.5	31.5	29.0	23.1	13.7	10.1	8.8	8.2
	1E—Well Supplies—Softened								
30 f	Elgin, Ill.	29.3	23.6	22.1	20.4	18.2	16.8	16.3	16.1
31 b	Maywood, Ill.	32.0	32.0	32.0	23.0	19.0	19.0	19.0	19.0
32 a	Marshalltown, Iowa	36.1	32.5	24.6	18.5	11.2	8.6	7.2	6.9
33 b	Benton Harbor, Mich.	37.0	29.3	26.0	18.9	9.5	7.2	6.4	6.1
34 c	LaGrange, Ill.	49.3	46.8	35.4	27.4	24.3	24.1	24.0	24.0
	AVERAGE	36.7	32.7	28.0	21.6	16.4	15.1	14.6	14.2

NOTES: a = 10 per cent penalty for delinquent payment.
b = 10 per cent deduction for prompt payment.
c = No penalty or discount shown on rate schedule.
d = No information available regarding penalty or discount.
e = After fifteen days, add 10 per cent on $3.00 or less, plus 3 per cent over $3.00.
f = 5 per cent deduction for prompt payment.
g = 20 per cent deduction for prompt payment.

TABLE 2 (contd.)

1F—Well Supplies—Not Softened

35 c	South Bend, Ind.	25.0	20.0	20.0	19.0	11.8	8.4	7.2	6.8
36 f	Rockford, Ill.	37.7	32.6	17.1	11.7	5.0	3.6	3.0	2.8
37 d	Aurora, Ill.	42.0	30.0	23.6	19.9	12.5	11.3	10.9	10.7
38 d	Dubuque, Iowa	30.7	29.1	22.3	17.5	11.1	8.8	7.8	7.5
39 c	Marion, Ind.	23.3	18.5	13.7	9.7	8.2	7.6	6.5	6.2
40 d	Chicago Heights, Ill.	42.7	38.0	24.4	17.8	8.1	5.8	5.0	4.8
41 d	Freeport, Ill.	38.0	38.0	38.0	24.8	11.9	10.7	10.2	10.1
42 g	Mt. Pleasant, Mich.	40.0	27.5	22.5	19.0	10.8	8.9	8.3	8.1
	AVERAGE	34.9	29.2	22.7	17.4	9.9	8.1	7.4	7.1

NOTES: See Page 1132.

TABLE 3

WATER SUPPLY DATA—WATER SOFTENING PLANTS—KEY TABULATION, POPULATION AND TYPE OF TREATMENT

0 to 6,000 Population

No.	City	Population	Type*	No.	City	Population	Type*
1	Galesville, Wis.	1,100	LSA	6	Homewood, Ill.	4,100	Z
2	Clarendon Hills, Ill.	1,300	Z	7	Western Springs, Ill.	4,500	LSA
3	Albany, Ind.	1,600	Z	8	Bicknell, Ind.	5,100	LSA
4	Elkhorn, Wis.	2,400	LSA	9	East Lansing, Mich.	5,800	Z
5	Westmont, Ill.	3,000	Z				

6,000 to 25,000 Population

10	Woodstock, Ill.	6,100	LSA	14	LaGrange, Ill.	10,500	LZ
11	Lebanon, Ind.	6,500	LSA	15	Benton Harbor, Mich.	16,700	LSA
12	Hinsdale, Ill.	7,300	LSA	16	Marshalltown, Iowa	19,200	LSA
13	DesPlaines, Ill.	9,500	LSA	17	Kankakee, Ill.	22,200	LSA

25,000 Population and Up

18	Maywood, Ill.	26,600	Z	23	Decatur, Ill.	59,300	LSA
19	Ottumwa, Iowa	31,600	LSA	24	Cedar Rapids, Iowa	62,100	LSA
20	Bloomington, Ill.	32,900	LSA	25	Springfield, Ill.	75,500	LSA
21	Elgin, Ill.	38,300	LSA	26	Fort Wayne, Ind.	118,400	LSA
22	Quincy, Ill.	40,500	LSA				

*LSA = Lime-Soda Ash.
Z = Zeolite.
LZ = Lime-Zeolite.

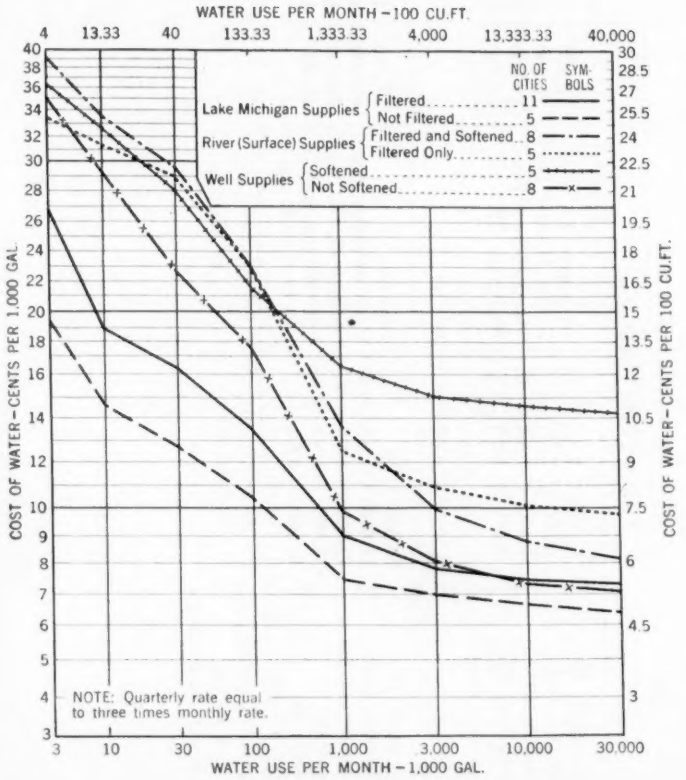
WATER USE PER MONTH – 100 CU.FT.
4 13.33 40 133.33 1,333.33 4,000 13,333.33 40,000
NO. OF CITIES SYM-BOLS
Lake Michigan Supplies Filtered 11
Not Filtered 5
River (Surface) Supplies Filtered and Softened 8
Filtered Only 5
Well Supplies Softened 5
Not Softened 8
COST OF WATER – CENTS PER 1,000 GAL.
COST OF WATER – CENTS PER 100 CU.FT.
NOTE: Quarterly rate equal to three times monthly rate.
3 10 30 100 1,000 3,000 10,000 30,000
WATER USE PER MONTH – 1,000 GAL.

FIGURE 1

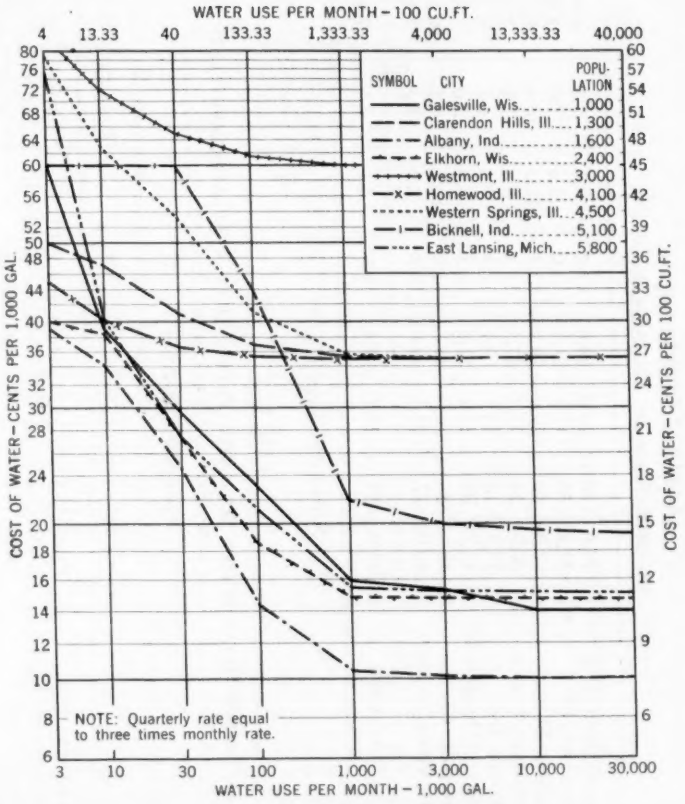
WATER USE PER MONTH – 100 CU.FT.
4 13.33 40 133.33 1,333.33 4,000 13,333.33 40,000
SYMBOL CITY POPU-LATION
Galesville, Wis. 1,000
Clarendon Hills, Ill. 1,300
Albany, Ind. 1,600
Elkhorn, Wis. 2,400
Westmont, Ill. 3,000
Homewood, Ill. 4,100
Western Springs, Ill. 4,500
Bicknell, Ind. 5,100
East Lansing, Mich. 5,800
COST OF WATER – CENTS PER 1,000 GAL.
COST OF WATER – CENTS PER 100 CU.FT.
NOTE: Quarterly rate equal to three times monthly rate.
3 10 30 100 1,000 3,000 10,000 30,000
WATER USE PER MONTH – 1,000 GAL.

FIGURE 2

FIGURE 1

FIGURE 2

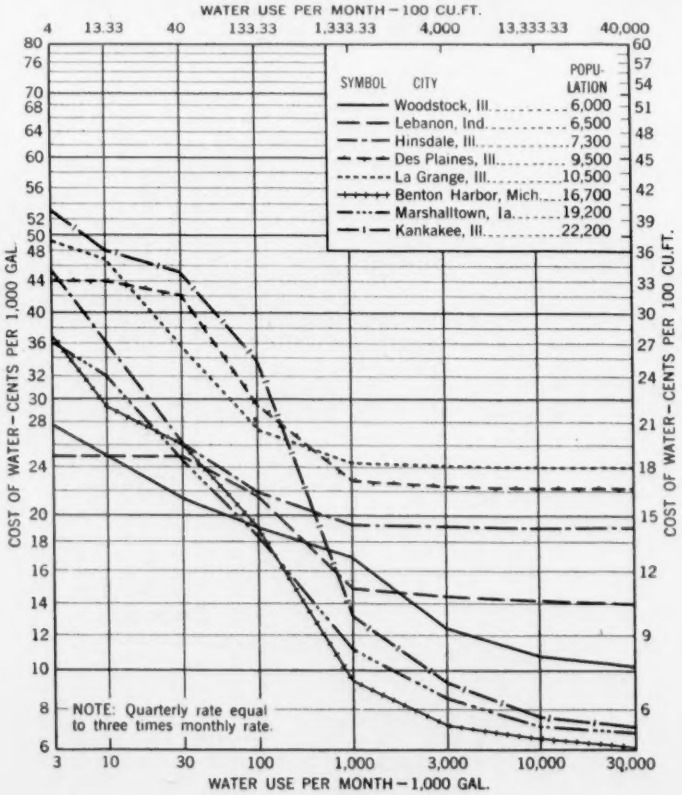
WATER USE PER MONTH – 100 CU.FT.
4 13.33 40 133.33 1,333.33 4,000 13,333.33 40,000
COST OF WATER – CENTS PER 1,000 GAL.
COST OF WATER – CENTS PER 100 CU.FT.
SYMBOL CITY POPULATION
Woodstock, Ill. 6,000
Lebanon, Ind. 6,500
Hinsdale, Ill. 7,300
Des Plaines, Ill. 9,500
La Grange, Ill. 10,500
Benton Harbor, Mich. 16,700
Marshalltown, Ia. 19,200
Kankakee, Ill. 22,200
NOTE: Quarterly rate equal to three times monthly rate.
3 10 30 100 1,000 3,000 10,000 30,000
WATER USE PER MONTH – 1,000 GAL.

FIGURE 3

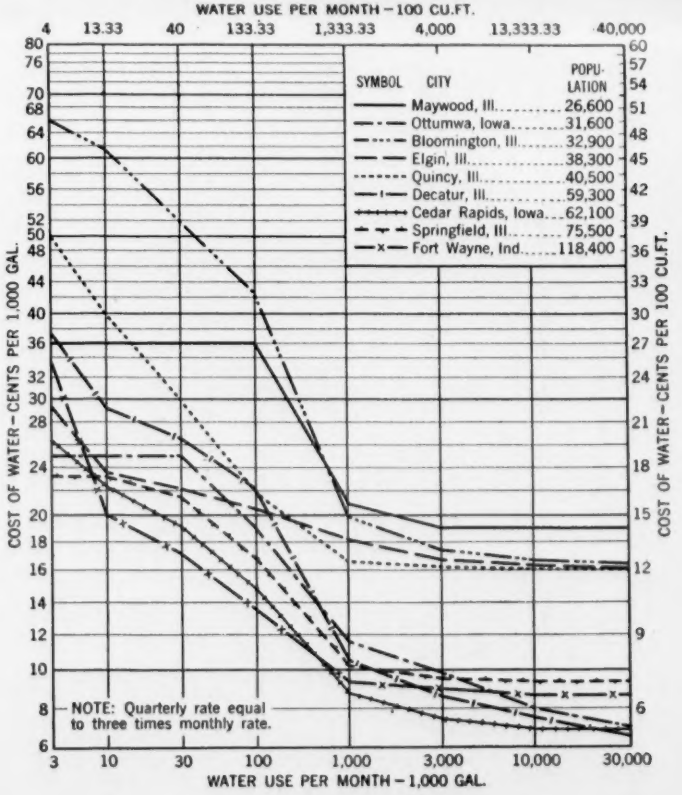
WATER USE PER MONTH – 100 CU.FT.
4 13.33 40 133.33 1,333.33 4,000 13,333.33 40,000
COST OF WATER – CENTS PER 1,000 GAL.
COST OF WATER – CENTS PER 100 CU.FT.
SYMBOL CITY POPULATION
Maywood, Ill. 26,600
Ottumwa, Iowa 31,600
Bloomington, Ill. 32,900
Elgin, Ill. 38,300
Quincy, Ill. 40,500
Decatur, Ill. 59,300
Cedar Rapids, Iowa 62,100
Springfield, Ill. 75,500
Fort Wayne, Ind. 118,400
NOTE: Quarterly rate equal to three times monthly rate.
3 10 30 100 1,000 3,000 10,000 30,000
WATER USE PER MONTH – 1,000 GAL.

FIGURE 4

TABLE 4

NET WATER RATES—WATER SOFTENING PLANTS—VARIOUS CITIES BY POPULATION GROUPS

0 to 6,000 Population

No.	City	Gal. per Month: 3,000	10,000	30,000	100,000	1,000,000	3,000,000	10,000,000	30,000,000
1 a	Galesville, Wis.	60.0	39.0	29.6	23.1	15.8	15.3	15.0	15.0
2 a	Clarendon Hills, Ill.	49.9	47.0	40.7	36.7	35.2	35.0	35.0	35.0
3 c	Albany, Ind.	39.3	34.0	24.7	14.4	10.4	10.1	10.0	10.0
4 a	Elkhorn, Wis.	40.0	38.4	27.5	18.5	15.0	14.8	14.7	14.7
5 b	Westmont, Ill.	81.7	71.8	64.8	61.5	60.1	60.0	60.0	60.0
6 b	Homewood, Ill.	45.0	40.0	36.7	35.5	35.1	35.0	35.0	35.0
7 b	Western Springs, Ill.	79.0	62.3	53.1	40.8	35.6	35.1	35.1	35.0
8 a	Bicknell, Ind.	60.0	60.0	60.0	43.5	21.9	20.0	19.3	19.1
9 d	East Lansing, Mich.	75.0	40.0	27.5	21.3	15.6	15.2	15.1	15.0
	AVERAGE	58.9	48.0	40.5	32.8	27.2	26.7	26.6	26.5
	6,000 to 25,000 Population								
10 c	Woodstock, Ill.	27.5	25.1	21.4	19.0	16.8	12.3	10.7	10.2
11 d	Lebanon, Ind.	25.0	25.0	25.0	21.6	14.9	14.3	14.1	14.0
12 b	Hinsdale, Ill.	45.0	36.1	26.1	21.8	19.4	19.1	19.0	19.0
13 c	DesPlaines, Ill.	44.0	44.0	42.0	29.3	22.7	22.3	22.2	22.1
14 b	LaGrange, Ill.	49.3	46.8	35.4	27.4	24.3	24.1	24.0	24.0
15 b	Benton Harbor, Mich.	37.0	29.3	26.0	18.9	9.5	7.2	6.4	6.1
16 a	Marshalltown, Iowa	36.1	32.0	24.6	18.5	11.2	8.6	7.2	6.9
17 b	Kankakee, Ill.	53.3	48.0	45.0	33.8	13.1	9.4	7.7	7.2
	AVERAGE	39.7	35.7	31.1	23.8	16.5	14.7	13.9	13.7
	25,000 Population and Up								
18 b	Maywood, Ill.	36.0	36.0	36.0	36.0	21.0	19.0	19.0	19.0
19 b	Ottumwa, Iowa	25.0	25.0	25.0	19.0	11.6	9.9	8.0	7.0
20 a	Bloomington, Ill.	64.8	61.3	51.8	42.2	19.9	17.4	16.6	16.3
21 f	Elgin, Ill.	29.3	23.6	22.1	20.4	18.2	16.8	16.3	16.1
22 b	Quincy, Ill.	50.0	40.1	30.0	21.8	9.1	6.9	6.2	5.9
23 d	Decatur, Ill.	37.6	29.2	26.4	22.0	10.5	8.6	7.6	6.6
24 d	Cedar Rapids, Iowa	26.3	22.3	19.4	14.8	8.8	7.4	6.9	6.8
25 c	Springfield, Ill.	23.3	23.3	21.6	16.8	10.3	9.7	9.4	9.4
26 c	Fort Wayne, Ind.	33.3	20.0	17.3	13.6	9.3	8.9	8.7	8.7
	AVERAGE	36.2	31.2	27.7	23.0	13.2	11.6	11.0	10.6

NOTES: a = 10 per cent penalty for delinquent payment.
b = 10 per cent deduction for prompt payment.
c = No penalty or discount shown on rate schedule.
d = No information available regarding penalty or discount.
f = 5 per cent deduction for prompt payment.

A Rate Structure for a Publicly-Owned Utility

Decision of Public Service Commission of Wisconsin

THE Public Service Commission of Wisconsin, on May 9, 1945, rendered a decision in a rate action brought by the municipally-owned and -operated Water Department of the city of Menasha which records so clearly certain fundamentals of rate making as to merit the publication of the decision in this JOURNAL. *Attention is invited to (1) the predication of a 5 per cent return upon the city-owned property as a proper part of the earnings to be made by the water utility; (2) the ruling of the commission that a rate structure should be based primarily upon the capacity cost of the plant required to serve each class of consumers and cannot be determined by an averaging of the cost of all water furnished; (3) the refusal of the Public Service Commission to permit the water utility to adjust its rate schedule by reducing the charge for public fire protection and increasing the rate to industrial customers; (4) the continuation of the commission's policy of requiring an adequate charge for private fire protection service, such as automatic sprinklers and private hydrants.*

The Public Service Commission's order and the prescribed rate schedule (Exhibit A) follow:

The Decision

BEFORE THE PUBLIC SERVICE COMMISSION OF WISCONSIN

Application of the City of Menasha as a Public Water Utility for Revision of Water Rates } 2-U-1640

Order on Reopening

Under date of Aug. 22, 1940, the city of Menasha, as a water utility, filed a petition to increase rates by the elimination from its rate schedule of the two lowest blocks thereof. Following hearing thereon, it was disclosed that the utility was primarily concerned with a temporary revision in rates to enable it to obtain experience upon which to base a permanent change in rates. After further hearing a temporary schedule was prescribed by order dated Feb. 6, 1941.

Under date of July 12, 1944, request was made by the Menasha Water Department that the Commission proceed with a further hearing in order to establish a permanent schedule of rates. Following such hearing on Sept. 1, 1944, the Commission, by order dated Dec. 22, 1944, prescribed a revised schedule of water rates.

On Jan. 17, 1945, the Menasha Water Department applied for rehearing. Although the right to rehearing, pursuant to Section 196.405(1) of the statutes had expired by the date the application was received, the Commission, by order dated Feb. 3, 1945, reopened the proceeding and issued notice of further hearing.

Hearing at Madison, Feb. 21, 1945, before Commissioner Whitney.

Appearances:

Menasha Water and Light Commission by
M. F. Crowley, Attorney
Members of the Water and Light Commission
M. O. Clinton
R. T. Frieders
A. F. Wickeham
John Jedwabny
P. E. Widsteen

Of the Commission Staff:
H. T. Ferguson, Chief Counsel
H. J. O'Leary, Chief, Rates and Research Department
P. A. Reynolds, Rate Analyst, Rates and Research Department

In its petition for rehearing the Menasha Water Utility alleged:

1. "That said rates as submitted to be followed and charged compel the commission to furnish water to the consumers at less than the cost of pumpage.

2. "That said rates as proposed by the order do not give the return on earning to the commission as purported by said order so to do.

3. "That said rates as proposed by said order are not practicable to operate said water utility."

The question of the insufficiency of the return permitted by the Commission's order of Dec. 22, 1944, arose due to a misunderstanding of the utility's application. The present record clarifies that issue and an adjustment in rates will be made herein so as to provide the utility with a return of approximately $30,000 or about 5 per cent on a net rate base which for this proceeding is assumed to be $606,720.

The utility alleges that the rates prescribed require it to furnish water at less than cost of pumpage. In support of this contention the utility presented certain exhibits and testimony purporting to show the cost of pumpage and the cost of delivering water in the mains. By dividing the source of supply, pumping, purification and distribution expenses by the total gallons pumped, the utility arrived at an operating cost of about 5.5 cents per 1,000 gal. delivered, exclusive of fixed charges. By adding depreciation and taxes and dividing by the gallons pumped, the applicant derives a cost of 9.92 cents per 1,000 gal. pumped.

Obviously the foregoing calculations represent only average unit costs. Their relationship to actual, properly allocated costs is remote. No consideration is given in such calculations to the substantial fixed and constant costs which properly are allocable to fire protection service. Apparently the utility made no attempt to separate and allocate the fixed, constant and variable costs applicable to the various classes of service rendered. In the absence of such determination, the average costs which have been calculated are meaningless.

While the general methods used by the Commission in determining costs of water service have been set forth many times over a long period of years, we believe it would be helpful to set forth herein in summary fashion the fundamental principles which are applicable and which justify the methods so used.

A water utility must be prepared at all times to furnish to all of its customers an adequate supply of pure and palatable water at a proper pressure so that such water will always be available for the user. To meet such requirements entails the erection of a plant consisting of source of supply facilities, pumping, storage, purification equipment, mains and hydrants of am-

ple capacity, meters and services. For the most part, the extent of the facilities above enumerated is based more upon the maximum potential demand for service than on the volume of water used. Consequently, a large proportion of the expenses associated therewith are in the nature of fixed and constant costs which do not vary with the amount of water pumped or sold. A relatively smaller proportion of the expenses, such as pumping and purification expenses, tend to vary directly with the volume of water output.

After total revenue requirements have been determined, it is necessary in designing a proper rate schedule that the several categories of expenses be properly allocated to the classes and kinds of service furnished. The two principal categories of service furnished are general service and fire protection service. The fallacy of using the average cost of furnishing any quantity of water in the determination of rates is well demonstrated in the case of fire protection service. Normally the volume of water involved in furnishing such service is negligible. At the most, a few fire streams a year used for periods of short duration account for the entire volume of water for short periods at a pressure sufficient to combat fires have a pronounced effect on the extent of plant facilities which must be installed. Aside from the relatively small investment in special facilities, such as hydrants and connections, oversize mains must be provided and source of supply, pumping and storage facilities must be of such size as to meet the heavy droughts of water required to combat fires. The costs incurred in such service are almost entirely of a standby nature and could not possibly be determined by the use of the average cost of all water furnished by the utility. They consist almost entirely of capacity costs and must be determined by allocation as between general service and fire protection service.

Within the general service classification capacity costs predominate, although output costs are important and must be given due consideration. The demands which the various general service customers are capable of placing upon the system constitute the proper basis for allocating capacity costs. These demands are determined from the size of meter connections. In this state, under methods followed by this Commission for many years, it is almost a universal practice to establish general service rates in such a fashion that most of the capacity costs are recovered from the customer by an initial service or minimum charge under which a fixed but limited amount of water is made available. Such minimum charge may properly be designed to recover not only the capacity cost involved, but also the output cost of furnishing a limited amount of water. But if, for any such minimum charge, water is furnished in excess of such limited amount, then full costs are not recovered, and a rate so designed would be unreasonable and in most cases discriminatory. With a schedule properly designed so as to recover most of the capacity costs in the service charge or minimum bill, it is possible to design reasonable rates for output or volumetric charges which ultimately, for large users, are only slightly in excess of the out-of-pocket cost involved in furnishing water to such users.

Large users who take service in fairly uniform amounts throughout the year absorb a considerable burden of the capacity costs and improve the utility's load factor, thereby reducing

unit costs. The loss of such customers would relieve the utility only of the output costs involved in their service and would leave a larger burden of capacity costs to be shared by the remaining customers. The importance of such customers to the Menasha Water Utility is demonstrated by the fact that industrial users take about 80 per cent of the water, whereas residential users represent about 92 per cent of the customers.

The application of the foregoing principles of cost allocation results in the allocations (below), based upon 1939 operations (1939 is considered to represent a more normal year).

If the utility is to earn 5 per cent on its indicated rate base, under the most logical procedure there should be no reduction in rates to any class of customers. To put into effect an $80-per-hydrant rate as proposed by applicant and still earn a full return would necessitate shifting about $6,500 of the indicated cost of fire protection service to general service. This procedure would be discriminatory. At [a rate of] $80 per hydrant, revenues of approximately $17,440 would be available from fire protection service. Compared to the costs, this would cover all operating and other expenses except the return, which would be reduced to $4,180 or to 1.97 per cent on the rate base assigned to this class of service. This loss should not under any circumstances be shifted to general service.

Testimony and exhibits were presented to indicate that the schedule proposed by the Commission, if properly applied so as to limit the amount of water included in the minimum bill to a fixed amount, would, no doubt, result in the installation of smaller meters for certain customers. Although our past experience would indicate a relatively slight shift, we have included a very liberal allowance for this factor in estimating the revenues under the rate schedule ordered herein.

The schedule of rates proposed by the applicant would reduce revenues from residential customers by about 5 per cent. Under the proposal this loss

	General Service	*Fire Protection Service*	*Total Cost of Operation*
Capacity or demand cost	$ 8,802.36	$ 2,826.15	$ 11,628.51
Variable or output cost	30,742.40	1,618.02	32,360.42
Direct charges to general	4,734.89	—	4,734.89
Direct charges to fire	—	132.05	132.05
TOTAL	$44,279.65	$ 4,576.22	$ 48,855.87
Tax equivalent	$ 6,153.00	$ 3,372.00	$ 9,525.00
Depreciation	9,693.00	5,312.00	15,005.00
Return 5 per cent on rate base	19,597.00	10,739.00	30,336.00
Total fixed charges	$35,443.00	$19,423.00	$ 54,866.00
Total cost	$79,722.65	$23,999.22	$103,721.87
1939 revenues	57,404.98	18,658.90	76,063.88
Deficit on 5 per cent return	22,317.67	5,340.32	27,657.99
1943 revenues	64,048.86	19,057.44	83,142.30
Deficit on 5 per cent return	15,638.23	4,941.34	20,579.57

would be made up by larger increases to industrial customers. Such a readjustment is not warranted on the basis of a fair and reasonable allocation of costs. The applicant also proposes to place in effect a fire protection rate of $80 per hydrant. Under that schedule, fire protection service would yield revenues about $6,500 per year less than full allocated cost including 5 per cent for return. The deficiency in revenue from such service should not be added to the costs borne by general service customers. However, if the utility desires a rate for fire protection service which would yield an annual net revenue of about $17,440 (resulting in a rate of return of slightly less than 2 per cent on the value of property assigned to such service), it should be permitted to do so, but only on condition that it accept a reduction in the return from that class of service, and that no part of such deficiency be included in the cost of general service. Rates for fire protection service cannot be properly based upon a per-hydrant charge, since the number of hydrants in use does not have a material bearing upon the cost of the service. Our order will, therefore, provide for optional or alternative rates for fire protection service, one based upon full cost of such service and an estimated 5 per cent rate of return therefrom, and the other based upon a lesser return resulting from a lower charge for such service.

It will be noted from the table on page 1140 that upon the basis of full allocated costs, including 5 per cent for return, the following are obtained: 1939 revenues result in deficits from general service of $22,317.67 and fire protection service of $5,340.32, or a total of $27,657.99; 1943 revenues result in deficits from general service of $15,638.23 and fire protection service of $4,941.34, or a total of $20,579.57. The rate schedules ordered herein are designed to increase revenues from general service by approximately $15,660 per year, after liberal allowance for reductions in meter sizes. The full-cost fire protection rate of $24,000 per year is $5,342 higher than the 1939 charge and $4,823 higher than the 1943 charge. We have reviewed operating revenues and expenses for both 1943 and 1944 and are satisfied that the proposed rates will yield the utility a full 5 per cent return upon a net rate base of $606,720. However, such increased revenues will be secured only if the schedule of rates is properly applied so as to limit the amount of water furnished under the minimum to 3,000 gal. per month, irrespective of the size of the meter.

Finding

THE COMMISSION FINDS:

1. That the schedule of rates as provided in the order of Dec. 22, 1944, should be modified.

2. That the schedule of rates as hereinafter ordered is fair and reasonable.

Order

IT IS THEREFORE ORDERED:

That the rates set forth in the schedule attached hereto as Appendix A are hereby prescribed to be charged by the city of Menasha as a water public utility of this state, the same to be effective upon the first billing date of said utility subsequent to this order.

Dated at Madison, Wisconsin, this 9th day of May, 1945.

PUBLIC SERVICE COMMISSION OF WISCONSIN

W. F. WHITNEY, *Commissioner*

SAMUEL BRYAN, *Commissioner*

Exhibit A

Municipal Fire Protection Service

It will be optional with the utility to elect to apply a basic charge as at June 1, 1945, of either $24,000 or $17,440 per annum for fire protection service supplied to the city, depending upon whether it is satisfied to receive a lower return on this class of service. This charge shall cover the use of mains and hydrants up to and including the terminal hydrant and connection on each line of main existing on May 1, 1945.

For all extensions of fire protection service a charge of 10 cents net per lineal foot of pipe shall be assessed per annum on the basis of the length of main put into use between hydrants placed, plus a fixed charge of $10 net per hydrant set for each hydrant added to the system.

All bills for fire protection service shall be rendered monthly and shall be for the charges which have accrued up to and including the last day of the month for which such bills are rendered for the service as above set forth.

This service shall include the use of hydrants for fire protection only and such quantities of water as may be demanded for the purpose of extinguishing fire only. For all other purposes the meter rates set forth herein shall apply.

In case of compound meters, the larger meter to determine the minimum charge.

There shall be an additional monthly charge to the minimum charge on all compound meters owned by the city of Menasha as a water utility, as follows:

8- and 4-in. combination	$ 6.67
12- and 6-in. combination	12.00

General Service Minimum Charges

Size of Meter, in.	*Per Month*
$\frac{5}{8}$	$ 1.00
$\frac{3}{4}$	1.50
1	2.33
$1\frac{1}{4}$	3.00
$1\frac{1}{2}$	3.50
2	7.00
$2\frac{1}{2}$	10.00
3	12.00
4	20.00
6	50.00
8	83.33
12	120.00

Consumption Charge

Gal. per Month		*Cents per 1,000 gal.*
First	3,000	Minimum bill for each size meter
Next	15,000	25
"	182,000	16
"	250,000	10
"	550,000	6
"	5,000,000	5
Over	6,000,000	4

General Service Payment of Bills

All bills, except bills for special readings, or for special purposes, and bills for public service, shall be dated on the last day of the month prior to the month in which bills are due and payable. Bills may be rendered at the net rates as hereinbefore set forth, plus a penalty of 10 per cent, the deduction of which is allowed providing payment is made on or before the tenth day of the month following the date of the bill. If the tenth day of the month falls on a legal holiday, the penalty will not be enforced until the twelfth, or after the next business day. The penalty will be waived on all bills accompanied by a remittance that has been postmarked not later than the

close of the business day on the tenth day of the month.

The penalty will be waived after the expiration of the net payment period once in every twelve monthly billings.

All delinquent consumers shall be subject to discontinuance of service. In such cases before service will be restored, a charge of $2.00 shall be collected to cover the cost of labor and incidentals in connection with the shut-off and turning on.

Private Fire Protection Service
(Unmetered)

This service may consist of connections for automatic sprinklers, private hydrants and standpipes (where same are connected permanently or continuously to the mains) and shall be entirely distinct from any other service rendered a consumer.

Size of Connection	Charge per Annum
in.	
4	$100
6	120
8	200
10	260
12	300

For metered private fire protection service the customer shall furnish the meter and setting where valves, drains, etc., are sealed and water is used only for fighting fires or testing. The flat rates referred to above will apply, plus any registration on meter due to leakage or illegal connections, which will be billed at the prevailing rate for water only.

For fully metered private fire protection service where hydrants, attachments, etc., are also used for other than fire fighting purposes, water shall be billed at the prevailing rate consisting of output charges and minimum service charges for general service. In this case the utility will furnish the meter.

For a metered tap on a private fire protection main, the metered water rates for general service, output charges and graduated minimum and service charges will prevail in addition to the charge for private fire protection service.

Billing rule for private fire protection service may be established on a monthly or quarterly basis, as determined by the utility.

Sleuthing in a Water Works Chemical Laboratory

By Earl J. Lynde and Frank E. Marks

Asst. Engr., Pasadena Water Dept., Pasadena, Calif.
Chemist, Pasadena Water Dept., Pasadena, Calif.

Presented on Oct. 26, 1944, at the California Section Meeting, Los Angeles, Calif.

IN order to serve consumers with water constantly fit for domestic consumption, the Pasadena Water Department early recognized the necessity of laboratory control, and, over a period of many years, systematic testing has proved to be of great value in maintaining supplies in a most satisfactory condition.

Most water works men are familiar with the well-equipped laboratory of a plant which treats water of a complicated nature, that is, water containing a surplus of undesirable constituents, or a combination thereof, which practically bar the raw product from domestic and industrial uses. Such supplies must be entirely changed at times, for nature, in creating streams and lakes, never intended that her fruits were to be utilized as man uses them, and man must transform the water for his own purposes.

The water must not be too hard, nor again too soft. It must not be as acid as nature sometimes leaves it after the decomposition of foreign material collected along its course. On the other hand, there is a limit to the alkalinity that may be present if the product is to be satisfactory. Even plant life frowns and withers when irrigation water contains salts which it cannot use, while customers complain loudly to the water company if smells and tastes offend them, if iron stains their fixtures or if lime clogs their heaters. It is here that the more technical laboratory becomes entirely essential in the struggle to correct the offenses.

A laboratory may be on the delivery end of a system where an imported water is received. In such a case, the laboratory serves a different purpose. The water may not exactly fulfill local requirements. Frequently several varieties of water must be mixed, contingent upon the season, as is the case in Pasadena where many deep wells and several gravity flows are used. There is little that can be done to change the mineral content of these fixed supplies if a softening or filtering plant is not established, but the measurement of decomposing organic matter and its possible detriment to health is constantly determined so that data necessary for preventive treatment are at hand at all times.

Each source of water is regularly examined in the laboratory and graphic illustrations of the salient points are charted for the files. Sampling from all parts of the distribution system is conducted so that possible corrosion or pollution may be spotted at any point on the line. By repeated analyses over a period of more than a quarter of a century the water character has been established, so that a glance at a report tells the source of a supply even if the name of the source is omitted.

By such constant vigil any departure from the norm as shown in an analysis is an alarm demanding attention. In such cases a well or stream is immediately discontinued and another source substituted until further investigations disclose the cause of perplexing change.

It may be seen, then, that there are two kinds of laboratories; one to determine treatment, the other to prevent trouble. Laboratories of a rather technical character necessary for complicated problems are no innovation and it is not the intention of the authors to add anything to their established routine. The authors desire to show how the laboratory can be valuable in smoothing out frequently baffling situations. The laboratory may be a very modest affair. It may be a spare room, a loft or a corner in a storeroom. It may not always be elaborate in design or equipment and yet its dignity and importance are unquestioned; for however small and obscure an undertaking appears, there is usually some technical aid which the laboratory can render. Manufacturers have taken the mystery out of many of the test tubes and glassware mazes, so that it is possible for almost any water plant staff member to carry out necessary tests.

Records of the Pasadena laboratory provide a few instances in which the laboratory clarified some odd circumstances, and indicated procedures to be adopted, thus ending nuisances. Tests have pointed the way to the end of perplexing problems, while at times lawsuits may have been averted. For example:

Proving Where the Water Came From

Several years ago the basement of a business establishment was partially flooded with water following a rain storm. It was the first time this had occurred and, because there was no visible evidence to the owner of storm runoff entering the basement, he accused the water department of being responsible, claiming that the water came from a leaking main.

A sample of the water in the basement was taken to the water company's laboratory for analysis and the basement and building were thoroughly inspected. This inspection revealed that the water could not have come from the main but that it probably came from a break in the soil pipe roof drain which passed through the basement and which was partially plugged at the gutter line.

The physical evidence was insufficient to convince the owner, so the analyses, as shown in Table 1, were shown to him and their significance explained.

The most significant proof that the water did not come from the city main lay in the calcium and magnesium content and the ratio of magnesium to calcium. Had the water come from the main it is conceivable that it might have picked up additional sodium sulfate from the debris on the floor of the basement, which was used as a paint shop and work room. However, it would not have lost calcium and magnesium to the extent reflected in the analysis of the basement water. The owner was convinced and withdrew his accusation, probably saving the water department considerable time, trouble and possibly the defense of a lawsuit.

Solving an Air-Conditioning Problem

In another example, a few simple laboratory tests and several years' records of microscopic analyses of city water solved an air-conditioning problem.

TABLE 1

Comparative Analyses of City Supply and Basement Water

Constituent	City Supply *ppm.*	Basement Water *ppm.*
Calcium	56.8	38.9
Magnesium	14.0	0.7
Sodium	18.3	80.7
Bicarbonate	229.0	176.0
Sulfate	21.7	103.0
Chloride	6.5	17.5
Total Alkalinity	188.0	144.0
Total Hardness	199.0	100.0
pH	8.1	7.0
Magnesium-Calcium Ratio	0.246	0.018
Sodium, %	16.6	63.8
Chloride, %	3.4	9.0
Character Formula	%	%
Calcium	29.6	17.6
Magnesium	12.1	0.5
Sodium	8.3	31.9
Bicarbonates	42.8	26.1
Sulfates	5.1	19.4
Chlorides	2.1	4.5

The lowered efficiency of the air-conditioning equipment of a large business concern led the owners to appeal to the water department because the manufacturers of the equipment had advised them that "something in the water" was responsible.

An inspection was made and a sample of the cooling water taken to the laboratory. On the roof of the building was a conventional cooling tower with a 187-gal. galvanized tank basin beneath the vanes from which the water was circulated through the air-conditioner by means of an electrically-driven pump. The water was kept at a constant level by means of a float valve. The entire amount of water in the basin and circulating system was estimated to be 200 gal.

The water was heavily infested with an algae growth, which was identified by microscopic examination to be a *Chlorophyceae* never found in any of the city's supplies. This evidence eliminated the city water as the carrier of the algae. The basin probably became infested with the spores of the organism being borne by the wind from some distant spot. A ½-in. layer of slimy deposit covered the bottom of the basin, showing that it had not been cleaned for some time. Further evidence of this was reflected in the values of alkalinity, pH and hardness shown in Table 2. Evaporation losses were

TABLE 2

Comparative Analyses of City Supply and Cooling Tower Water

Constituent	Cooling Tower Basin, *ppm.*	City Supply, *ppm.*
Total Alkalinity	468	181
Carbonate Alkalinity	90	0
Bicarbonate Alkalinity	378	181
Hardness (Soap Method)	565	162
pH	8.7	8.0

replenished through the float valve but the salts contributing to the alkalinity and hardness remained and became highly concentrated. This condition was conducive to a deposition of calcium carbonate in the system, thus reducing the flow as well as the cooling capacity.

The concern followed the water department's recommendation that the basin be thoroughly cleaned, the system flushed and the water changed every two weeks, thereby inhibiting the growth of algae, preventing the concentration of salts and retarding the deposition of calcium carbonate. No further trouble has been reported during the five years since this procedure was adopted.

Tracing a Leak

During the last rainy season a trickle of water started flowing from a small crack in the pavement about 15 ft. from the curb on one of Pasadena's main thoroughfares. The leak persisted after the street runoff had ceased. The service records and maps indicated no service taps to the main in the near vicinity and it was undesirable to rip up the pavement in a blind search for the leak. The theory was advanced that the water was flowing under the pavement from a leak in a storm drain which crossed the street uphill from the leak and that pressure was forcing it through the crack.

However, the flow continued and finally, since the leak detector was away for repairs, the laboratory was requested to make an analysis of the leakage water as a possible clue to its source. This analysis, as well as analyses of a sample of storm water and water from the street main, is shown in Table 3.

TABLE 3

Constituent	Lake Ave. Seepage *ppm.*	Sunset System *ppm.*	Typical Street Runoff *ppm.*
Calcium	43.2	40.8	7.2
Magnesium	18.0	15.1	0.0
Chlorides	11.5	11.5	0.9
Total Hardness	182.0	164.0	18.0
Total Alkalinity	160.0	159.0	12.0
Noncarbonate Hardness	22.0	5.0	6.0
CO_2 (calculated)	5.1	3.2	1.5
Chlorine Residual	0.05	0.2	0.0
Magnesium-Calcium Ratio	0.416	0.370	—
pH	7.8	8.0	7.2

These analyses clearly showed the source of trouble to have been the city supply. In addition, the repair division was advised that the leaking pipe would probably be found uphill from and fairly close to the point of emergence of the water through the pavement, since the chlorine residual of 0.05 ppm. would not have remained if the water had traveled very far through the ground.

Excavation was begun at the leak in the pavement and less than 15 ft. from there the crew uncovered an old, abandoned, leaking service of which there was no record.

Tracking Down a Magic Carpet

During a spring inspection trip of the Arroyo Seco, which is Pasadena's main gravity source of supply, it was discovered that the submerged rocks a few miles above the system's intake had taken on a gorgeous red color.

There was no deposit on the rocks which could be scraped off, so several of the small stones were taken to the laboratory and given a bath in dilute hydrochloric acid. This restored the natural granite appearance of the rock. The dissolved matter proved to be iron.

The small tributaries of the Arroyo were perfectly clean and no one had ever seen the main stream so highly decorated. Thinking that the laboratory might play detective in running this down, men with a portable outfit started on the lower end of the stream. The pH around the intake was normal at about 8.3 and continued to be so until well within the red area. It began to drop while the normal carbonate faded out. Continuing along the stream, it was found that the pH gradually became lower until Brown Canyon Dam, a debris barrier built in 1942 by the U.S. Forestry Department, was reached. The water at the base of the structure showed a pH of 7.4 but still no cause was apparent.

With the aid of ladders, the men climbed over the dam to the stream

above, where a small tributary stream was discovered. It had the tell-tale red rocks, but the bed of the main stream above the tributary was uncolored. The tributary was explored and a "magic carpet" was found several hundred feet upstream. The "magic carpet" appeared to be thick felt-like blankets of many hues. Nearby was a foul bog giving off gas. The water here had a pH of 6.2. The little laboratory device had led to what the microscope later revealed to be a rich bed of *Crenothrix* nestling under the shadow of the hillside shrubbery.

Brown Canyon Dam is located in the Arroyo Seco approximately 3.3 mi. above the Pasadena Water Department intake. Runoff from the rains of the last two winters has deposited sand, gravel and debris to a depth of half the height of the dam. The Arroyo Seco stream meanders over the top of this deposit to an outlet tower and discharges at the bottom of the dam into the stream bed.

About 300 ft. above the dam, this meandering stream receives the discharge from a bog which lies against the west side of the canyon. The bog was probably caused by the concentration of floating debris in back eddies at this location during the flood runoff of the winter of 1942–43. The surface of the bog is 5 or 6 ft. below the level of the stream which is about 150 ft. east of the bog. Underflow from the stream supplies the bog whose surface is matted with a black layer of decaying leaves, twigs, etc., and the entire area is in an active state of decomposition. Large bubbles of gas, including methane or marsh gas and carbon dioxide, are continuously breaking the surface. There is no perceptible odor around the bog, but the water when smelled from a bottle has a disagreeable, putrefactive odor.

The water discharging from the bog has a sickly grayish color and supports a growth of typical, although unidentified, water fungi, which covers the stones of the bottom and clings to submerged sticks and other debris. In places the fungi are bulbous in form, like summer clouds; where there is more current the masses are more shaggy or fleecy with jagged edges and show points swaying in the current, resembling cotton wool in appearance. They also attain a purple color in some locations, although under the microscope they appear quite colorless and devoid of chlorophyll. Individual organisms are filamentous, from 15 to 20μ in diameter, with very few cell divisions. They are sparsely granulated and carry long, profuse, hair-like growths emanating from the ends and from irregularly spaced nodules along the filament. These growths are barely discernible under a magnification of 100 ×.

The stream bed carrying the water from the bog to the main Arroyo Seco channel is heavily infested with *Crenothrix,* a filamentous iron bacteria having a gelatinous sheath colored a brownish red by a deposit of ferric oxide and growing in tufts matted together into felt-like layers.

Crenothrix may be found in the stagnant water at the bottom of a deep lake and has been observed in swamps in company with *Anabaena* and other *Cyanophyceae.* It may grow in almost any part of a ground water system—in driven wells, reservoirs or distribution pipes—and develops especially luxuriantly about woodwork. It grows abundantly in waters containing iron and manganese. (Note iron content of 8 ppm. as Fe in analysis of bog

water, Table 4.) Sometimes its growth and the precipitation of iron or manganese is so great that services and small mains are completely clogged. Dying *Crenothrix* decomposes, gives off disagreeable odors and may impart bad tastes to the water.

The wetted rocky stream bed of the Arroyo Seco, from the confluence of the bog discharge to the outlet tower, is stained a dark brownish red from the iron precipitated by the *Crenothrix*. Rocks above the water line for a vertical distance of about 18 in. are stained the same color, but above them is a layer having a distinct yellow stain.

On May 26, 1943, water samples for laboratory analyses were taken from (1) the clear stream above the bog; (2) the discharge from the bog; (3) the mixture of clear stream and bog water as it was discharged from the dam; and (4) Arroyo Seco at the intake after flowing 3.3 mi. down the canyon. The results of the analyses are shown in Table 4. The pH and alkalinity were determined in the field; calcium and magnesium were determined by the soap method and sodium was computed.

The low pH, high CO_2, extreme hardness and absolute lack of dissolved oxygen make this bog water even worse than the discharge from Devils Gate Tunnel which had to be abandoned several years ago. The worst feature is the perfect environment it provides for the growth of such organisms as *Crenothrix*. As may be seen in Columns 3 and 4 of Table 4 the dilution with the clear stream water (Column 1) plus aeration eliminates the undesirable chemical characteristics, but the menace of the *Crenothrix* filaments being carried into the reservoir remains.

A distinct odor of hydrogen sulfide permeates the atmosphere below the

TABLE 4

Arroyo Seco Water Analyses as of May 26, 1943

Constituent	1 Arroyo Seco Above Dam Above Bog	2 Bog Above Brown Canyon Dam	3 Arroyo Seco Below Dam 1 + 2	4 Arroyo Seco at Intake 3.3 mi. Below 3
Temperature, ° F.	61	61	61	63
Odor	0	5d	4S	0
pH	8.0	6.4	7.4	8.2
Total Alkalinity, *ppm.*	146.0	303.0	166.0	170.0
CO_2 (computed), *ppm.*	2.9	241.0	13.2	2.1
Total Hardness, *ppm.*	148.0	303.0	163.0	175.0
Ca	32.4	70.8	39.2	41.2
Mg	16.3	30.7	15.8	17.5
Na + K	19.8	12.0	19.6	20.7
Iron as Fe	—	8.0	—	—
CO_3	0.0	0.0	0.0	0.0
HCO_3	178.0	370.0	203.0	207.0
SO_4	31.0	9.5	24.7	33.7
Cl	9.0	11.0	9.5	10.5
$CaCO_3$	+0.14	−0.86	−0.32	+0.51

dam but is not discernible above the dam. This colorless, inflammable, poisonous gas may originate from iron pyrites and other ores or it may be the product of anaerobic decomposition of sulfur found in the complex structure of the dead cells of organic matter. Since the content of iron and dead organic matter in the bog is high, they both probably contribute to the formation of the gas found below the dam. There was no perceptible odor of hydrogen sulfide in the bottle samples of water and it is quite possible that the distinct odor below the dam was due to the pocketing of the heavy gas (sp. gr. 1.17) eliminated by aeration in the outlet tower, at the base of the dam.

As the water picks up dissolved oxygen on its way downstream from the dam, the sulfur carried by the organic load is oxidized to sulfate, which accounts for the increase in sulfate between the dam and the intake.

The immediate effect of the bog water on the stream is not reflected in the tables, since sample No. 3 was taken after the mixture had flowed over about 300 ft. of gravel channel bed and then dropped about 40 ft. in the outlet tower which provided excellent aeration for the elimination of carbon dioxide, methane and hydrogen sulfide and the replenishment of dissolved oxygen. This water is joined by the leakage from numerous seep holes through the dam which has percolated from the stream down through the organic debris behind the dam. The ultimate effect is reflected by the difference between the analyses in Columns 1 and 4, plus the all-important menace of *Crenothrix*.

It is hoped that these few instances picked from Pasadena's records may serve to show how the laboratory might always be given first thought as an aid to solving problems which at the outset may appear to have little to do with such an establishment.

Operation and Maintenance of Plant Equipment

By Carl M. Hoskinson

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Presented on Oct. 25, 1944, at the California Section Meeting, Los Angeles, Calif.

IT is intended here to present the problems of operation and maintenance of equipment in general, but it is not intended that this discussion be considered a directive for the operation and care of any particular piece of equipment, as such directives are more suitably found in detailed instructions from the manufacturer.

Failure of equipment is generally the result of one of three causes: (1) ordinary wear and tear, (2) accident, (3) neglect. The first cause is inevitable, but the resultant failure can be postponed by careful and intelligent operation. Accidents may often be prevented. Neglect is probably the greatest single cause of trouble and is inexcusable either on plea of economy or failure of maintenance plan.

Deterioration of equipment is caused by several factors, such as friction, corrosion, electrolytic action, breakdown in dielectric strength and factors related to each. All of these phenomena are familiar, although the failures caused by their action sometimes occur because danger signs have not been noted in time to remove the cause or to make repairs before complete failure and destruction occur. In the author's opinion the best insurance for continuous and trouble-free operation is to install the best available equipment for the service, intrust its operation to a picked crew of well-trained and intelligent operators, and then place its care in the hands of a full-time expert mechanic or crew of mechanics charged with the duty of keeping it in running order. It is very helpful in care of equipment if the operating crew is composed of men with mechanical training or natural mechanical ability, as such men will often detect and avert approaching trouble by visual or audible signs, whereas men of little natural mechanical aptitude not only do not sense impending trouble but often cannot tell the cause of same or make emergency provision for repairs after the trouble occurs.

The care of equipment should not be intrusted to an outside shop or to transient maintenance men unfamiliar with the needs or functioning of equipment, but should be handled by men who are part of a regular maintenance crew trained at the plant, familiar with and interested in the correct functioning of the equipment. Such a crew will always be on the lookout for possible trouble. The location of possible sources of trouble before it occurs makes their work lighter, increases their interest in their work, makes costly and disagreeable shutdowns infrequent or nonexistent and reduces long night hours and overtime work to a minimum. Since full-time operation of water systems is vital, it is necessary to have "on call" mechanics and usually electricians also, in case of

emergencies. Such an arrangement pays big dividends in the insurance of continuous plant operation.

Friction

Friction is possibly the chief offender in causing operating trouble but it is also the most easily recognized, as the call for help which comes from the activities of this little "gremlin" is not uncertain and is often vociferous. Friction always occurs to a certain degree between any two substances between which there is relative motion but the problem of its appeasement is not difficult when the most suitable oil or grease available is used. However, in the case of slow-moving bodies, such as sluice gates and valve discs, particularly under water, such lubrication is not possible and the use of suitable adjacent metals with the lowest coefficient of friction becomes necessary.

An interesting problem in this class occurred in the operation of double disc gate valves equipped with bronze shoes sliding on machined guides on cast-iron valve bodies. These 24-in. valves of the square-bottom type were used to control wash water in filter washing and were supposedly built for throttling service. It was found, after a few years' operation, that the sliding shoes were cutting the valve bodies badly on both sides. The abrasive action apparently was increased by rust particles, which acted as a grinding compound. This abrasion did little damage to the replaceable bronze shoes, but so badly grooved the iron valve bodies, which were not readily replaceable, that there was danger of failure of same. The problem was critical, as the valves were essential to filter operation and repair could only be accomplished by replacing the valve bodies or by eliminating the cutting action. The wear on the valve bodies was finally eliminated by having a pair of Monel metal tracks made to order for each valve and bolting them in place on the valve body. They were designed thus: Special Monel metal angles, about 30 in. long, to reach the full distance from the valve bottom to the bonnet flange with equal $1\frac{1}{4}$-in. legs, were bent so that the internal angle was nearly square. These were so placed in the valve body that the bronze sliding shoes ran on one inner face of a Monel angle on each side of the disc and the other face of the angle was used to bolt the angle solidly to the outer side of the valve body. The square bottoms made it possible to carry the outer face of the angles right down to the valve bottoms, while the "slide" side of the Monel angles was cut away about 6 in. at the bottom to allow the shoes to move toward the flange side of the valve body so that valve discs would seat properly. For bolting the Monel angles to the cast-iron valve body, $\frac{3}{8}$-in. countersunk brass bolts were used which passed entirely through the bodies of the valve and were supplied with brass nuts and washers and steel lock washers on the outside. To prevent leaks, holes were drilled in the valve bodies for a neat fit and slow-settling "Permatex" was applied to and under the bolts. A brass washer, followed by a steel spring washer and a $\frac{3}{8}$-in. brass nut, was applied to each bolt outside the valve body. The Permatex was thus squeezed tightly in place and prevented leakage. The representative of the valve manufacturer was very dubious about this repair, fearing that the Monel guides would not stay in place. However, these guides, which have now been in place over eight years, have already proved more reliable and longer lasting than the original slide seats on the

valve bodies, and no sign of failure has occurred.

Normally, in gates and valves, allowance is made for compensating for friction by the replacement of faces of valve and gate seats and discs. This is a routine matter with competent mechanics, although in the case of large sluice gates considerable labor is involved. In some sluice gates, brass seats have been placed by extruding the metal into dovetailed guides in the cast-iron seats. In such a case, it is possible to make field repairs only by using flat brass and countersunk screws, which, however, usually last nearly as long as the original seats. In one installation a large sluice gate is used for throttling operation to feed water through mixing tanks, and considerable wear on seats and gate-wearing surface occurs. When throttling operation is necessary, as in filter control or automatic or hand control of basin levels, much better and wear-free operation is obtained by the use of large single or double disc valves of the globe type. Filter control was originally by gate valves in the plant under discussion, but this control has been entirely replaced by float-controlled, special double disc valves, similar in operation to a globe valve. There is practically no wear on these valve parts except the slight wear caused by pressure on the babbitt seats when the valves are closed.

Lubrication

A plant should keep in stock several varieties of lubricants, particularly where operations are complex and a large variety of equipment is handled. It is best to use the smallest number of lubricants possible, as this will lessen the possibility of making wrong applications. In general, high speeds require lighter oils, while heavier oils are called for as speeds decrease, and the various grades of grease are used on the slower speeds. As grease is practically an adulterated oil, it is best to use oil of the best quality wherever possible. However, slow-moving equipment, particularly in the open, usually is best protected by grease, especially if allowed to stand idle for any considerable period. Fortunately, some manufacturers are now producing oils and greases with rust inhibitive qualities, which should be a great protection to equipment, particularly that which may be out of service. The lubrication and protective care of plant equipment by proper greases and oils is a matter worthy of careful consideration. It has been found that careful temperature tests of different oils under the same conditions yield rather surprising results. In one case, an oil affording operation at a few degrees lower temperature did not justify its cost, as compared to a lower-priced oil which kept the bearing temperature well within safe limits. Each different case of lubrication should be attacked as a new problem, and lubricants should be tailored to each particular job.

Bearings

Bearings for normal duty are usually either sleeve bearings or ball bearings. Bearings for heavier duty are Marine thrust, ball thrust, roller, Kingsbury, spring thrust and others. While many will not agree, experience at the Sacramento plant has shown that sleeve bearings will give far longer service without trouble than ball bearings, though their friction coefficient is higher and their replacement usually more difficult. Many sleeve-type bearings have been in almost continuous operation for twenty years and show no signs of wearing out, but many bear-

ings of the ball type have not given equal service. However, the high efficiency and ease of replacement has led to a wide application of ball bearings, and, with proper care and lubrication, they will give many years of trouble-free service. Ball bearings are particularly susceptible to the ravages of corrosion, which may be caused by moisture in oil or by condensation. It has been found at Sacramento that, particularly for ball bearings, an oil of pH = 7.0 (or neutral) should be used, though it has been noted that some high-grade oils lean slightly to the alkaline side. It appears that oil in service tends to decrease in pH, toward the acid side, and for this reason it is held that a change of oils long before indications of darkening color is a good investment, as any lubricant in almost any quantity is cheaper than a bearing or equipment failure.

Corrosion

Protection from corrosion is an economic problem, as well as one of protection only, for attempts at protection may be misguided and overdone. For instance, if a high-grade cast-iron sluice gate will give satisfactory and trouble-free service for a minimum of 50 years under water, and many have done and will do so, it appears self-evident that periodic scraping and painting is a waste of money. However, tuberculation and corrosion of the gate stem in such a gate would result in pulling guide bearings or the brackets supporting same off the walls and would thus require periodic attention. Hence an original installation or replacement of such stems by Tobin or other bronze is a good investment. Likewise, if a steel line or structure subject to corrosion will last without attention beyond the useful life of such structure, or until outgrown or outmoded by greater needs, its preservation is obviously a waste of maintenance time and money, for, when removed, it will generally be sold as scrap. However, such reasoning does not apply to structures whose period of usefulness cannot be definitely foreseen, which is the case in most treatment plant systems.

The usual methods of combating corrosion by applications of paints or enamels are normally not effective in acid conditions where linings of lead, rubber, glass and synthetics are indicated. The latter seem to be a very important contribution, and it is expected that plastic products and linings of synthetic materials will have a wide field of application in the postwar world. Tests of some of this material have been made under severe conditions of hot diluted sulfuric acids and very favorable results have been obtained, although the manufacturers do not recommend this material for use above about 150°–160°F. Lead seems to be the best acid-resistant lining material. General and widespread experience has been, however, that it is difficult to hold such linings in place, as they "crawl" under heat and do not spring back, because of the inertness of the material.

In general, protective coatings for corrosion resistance consist of paints of many bases and conveying vehicles, principally with metal bases and oil or synthetic vehicles, asphalt paints and dips and coal-tar paints and enamels. While good protection can be obtained by the use of cold application paints, particularly by red lead and linseed oil and red lead in combination with certain synthetic varnishes, experience at Sacramento, after a trial of many brands, indicates that nothing in the way of applied coatings gives better

protection from corrosion than a high-grade coal-tar enamel applied about $\frac{3}{32}$ in. thick over a thoroughly cleaned surface which has been coated with a coal-tar cold priming solution. Such a treatment is of practically no value, however, unless, after applying the enamel, a high-tension spark test above 5,000 v. is applied to the *entire* surface so coated to detect any possible pinholes or "holidays" in the coating, which must be marked and immediately re-coated.

Another method of protecting certain structures, particularly isolated ones such as tanks and pipelines, is the installation of the cathodic protection system. The author has had little personal experience with the process, but believes that it has great possibilities when intelligently applied and operated. Of course, its operation involves the continuous feeding of direct current at low voltage to the structure to be protected and a continuous source of power is necessary. The author recommends that this system be thoroughly investigated where a major protection problem arises to find whether it fits the particular case.

Electrolytic Action

The development of trouble by electrolytic action is slow and not always recognizable until the action has progressed to the point of failure. Electrolytic action occurs in a greater or lesser degree when two dissimilar metals, particularly those spaced far apart in the emf. series, are closely connected in the presence of even a weak electrolyte, such as water. The degree of interaction between the two metals seems to vary inversely with the degree of perfection of the bonding between the two metals. For instance, in the case of a brass seat ring, screwed with a loose or "sloppy" fit into the cast-iron threads of a valve body, it has been found that electrolytic action will so destroy the cast-iron thread as to allow the brass seat ring to become loose and fall out and be crumpled into a worthless piece of junk by the closing of the valve disc. This action may be, and usually is, caused by the couple formed between the cast iron higher in the emf. series and the brass, lower in the series, causing the flow of current from iron to brass in the presence of an electrolyte. This action is aggravated if there are any stray ground currents in the area which might tend to flow in their natural course from iron to brass, but it is believed that the trouble is generally, if not always, caused by the difference between the two metals in the emf. series.

The author, in blissful ignorance, at one time thought it would be a good idea to lighten the weights and improve the action of an hydraulic engine, which was operating large paddles at slow speed in 40-ft. coagulation tanks, by substituting aluminum pistons for worn cast-iron pistons which had operated in cast-iron cylinders. The results were very positive but not very pleasing, for electrolytic action between the aluminum and the cast iron soon froze the pistons in the cylinders with a filler of aluminum oxide which made a difficult job of removal. Needless to say, new cast-iron pistons were soon installed in these engines. This trouble does not occur in automobile engines using aluminum alloy pistons, probably because there is an insulating oil, rather than an electrolyte such as water, between the two metals. It may also be that the aluminum alloy is so proportioned as to be closer to cast iron in the emf. series, but this seems improbable.

Another common and easily observed effect of electrolytic action often occurs in threaded joints, particularly in steam and hot water lines where cast-iron fittings, such as elbows and tees, are used in conjunction with black steel pipe. Anyone who has occasion to repair leaks in such lines will often find that they generally occur first in the threaded joints where destruction of the thread on the pipe occurs, because of electrolytic action. This is likely to occur more often in any point in the line where there may be a collection of moisture. For this reason, it is better practice to use malleable fittings with steel or wrought-iron pipe to lessen greatly this tendency toward trouble by electrolytic action.

A very pronounced case of electrolytic action occurred when several 36-in. sewage pumps gave trouble after several years of operation. The trouble was first noted when the amperage on the motors driving the pumps dropped and the pump capacities decreased sharply. The pumps were opened for inspection, and it was found that, although the pumps were fitted with the specified bronze runners, an unauthorized and hitherto undetected substitution of cast-iron or cast-steel wearing rings had been made for the bronze rings which had been expected. The manufacturer probably had no ulterior motives in placing cast-iron or cast-steel rings on these pump runners, as they had been carefully installed and doweled with steel pins screwed in. What actually happened, however, was that the cast-iron threads and the threads on the dowels were eaten away in the presence of the sewage, an electrolyte somewhat stronger than water. The bottom ring dropped off the runner and the upper ring was loose, thus causing a short circuit in flow between discharge and suction passages and reducing pump capacity and motor amperage. The situation was remedied by making new bronze runner wearing rings and welding them to the runner, as there was not sufficient remaining stock on the runner to turn new threads. It should be emphasized that this electrolytic action is greatly minimized and almost eliminated if there is a perfect electrical bond between the two dissimilar metals, such as tight threads in red lead or good conductor, and if the electrolyte (water, sewage, weak alkaline or acid solutions) is excluded from contact with the two metals where they contact each other. It is our belief and experience that this action is greatly lessened or eliminated if the two metals are welded or brazed together, making a joint with little or no potential difference. Such a connection is not always practical, but tight joints are necessary and possible to obtain.

Breakdown in Dielectric Strength

The operation of water works except in the cases of some standby units, is becoming almost exclusively dependent on electrical prime movers and electrical control. This is due to the fact that the power networks have become so interlaced that power failures, for anything but very short intervals, are almost unknown, and electric power from a large system, particularly if fed from several points, is likely to be more dependable than a local independent power unit. In large systems this leads to a rather complex installation of circuit-breakers, switches, transformers, motors, starters and auxiliary control equipment. Such an installation requires careful watching by expert eyes and proper testing equipment if approach of trouble is to be dis-

cerned and precautions taken to prevent it. The operation of equipment at voltages up to 500 v. does not involve such intensive attention to equipment insulation, but when the horsepower of individual motors reaches or exceeds 50 and the total installed horsepower of motors runs into hundreds, the motors should, and usually do, operate at 2,200 v., to save in size of cables, conduits and control facilities. Operation at 1,100, 2,200 or even 6,600 v. is no more difficult and not much more dangerous if the equipment is initially of proper size and capacity for the work, and, more particularly, if proper facilities, such as test and maintenance equipment, are provided to keep it in order. The dielectric strength of any piece of electric equipment is measured in ohms or multiples thereof, such as the megohm, and is the measure of its resistance to breakdown by electric potentials. A small, portable, easily used piece of testing equipment, called a "megger," is available in several forms and capacities. It affords a simple means of testing the insulation of motor windings, cable and wiring installations and all electrical equipment and determining, by comparison of the test results with standards for that operating voltage, whether any trouble may be developing. These tests are so positive and their results so dependable that, when made systematically and understandingly and when corrective measures are applied, there is no need for carrying any insurance on electrical equipment to cover internal failures. Such insurance is expensive, and, although well backed up by reliable companies, is, in our opinion, not so effective as the personal attention of a plant electrician.

In the case of transformers and oil circuit breakers, the insulating dielectric is a thin mineral oil, the testing of which is made, not by a megger, but on a standard spark testing set which is usually set to break down a film of oil 0.2 in. thick, at 22,000 v. or over. Testing of such oils is easily accomplished and oil testing and filtering units are necessary pieces of equipment where transformers and oil circuit breakers are operated. One is often surprised by the deterioration and lessening in dielectric strength in insulation of motors and cables, and transformer and switch oil from no apparent cause, but this incipient cause of trouble can readily be detected by the use of the equipment indicated. An electrical breakdown is almost always accompanied by a burned-out motor winding or an exploded and burned-out transformer and it occurs so rapidly that even the best and properly regulated protective devices (which are usually set to allow some overload) are not quick enough in their action to prevent the release of hundreds and sometimes thousands of electrical horsepower into station equipment in a hungry and all-consuming flash of electrical fire, with a destructive force often exceeding that of lightning. Many other aspects of the care and maintenance of electrical equipment of water plants are usually well covered by detailed instructions from the manufacturers of the equipment used. It is well to follow these closely, bearing in mind that conservatism is a good rule to follow, and remembering to rate the capacity of any piece of equipment from 10 to 25 per cent below a manufacturer's rating. Except when this results in decreased efficiency, it is good practice and results in long life for the equipment. This is particularly true in current control devices, such as circuit breakers, which, due to electrical

failures in equipment, may be called on to interrupt current flows greatly in excess of their ratings, in which case excess capacity is a good investment.

Summary

It should be stressed that the best results in operation of any plant can be obtained only if:

1. The equipment is best of its kind, of capacity properly adapted to its intended use and expertly installed. In short, no misfits and nothing but expert installation.

2. Members of the operating staff are intelligent, loyal, interested in their work and competent.

3. The maintenance crew is composed of full-time, competent, experienced mechanics, who are loyal and eager and who take pride in keeping equipment in perfect operating condition. It should be obvious that such men should be fully supplied with tools, test meters, gages and any testing equipment necessary to keep close check on all equipment.

While such conditions may seem to approach a Utopia, it is not impossible to accomplish, and the objective, which is continuous trouble-free delivery of a domestic water supply for all purposes, justifies extreme measures, if necessary, to assure its accomplishment.

Cross-Connection Control and Elimination in California

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Presented on Oct. 26, 1944, at the California Section Meeting, Los Angeles, Calif.

HISTORICALLY, the California State Department of Public Health has always been concerned with cross-connections and their effect on the control of water-borne disease. Prior to the war, control was directed toward preventing cross-connections between drinking water and sewage and toward prohibiting or protecting cross-connections between approved and unapproved sources of supply. With the advent of war and the resultant increase in water use, the demand for auxiliary supplies for fire protection and other uses resulted in a large number of connections between drinking water and waters unsuited for human consumption. These connections constitute a definite health hazard unless the drinking water is protected against backflow of the dangerous water.

The history of control of cross-connections in California began with a State Board of Public Health regulation adopted in November 1919, and amended May 1924. If a water department wished to continue to supply premises having their own private supply, and if the two systems were interconnected, the law required that the water department should hold a permit for the private supply as well as for the public supply, on the ground that the private supply constituted a potential portion of the water which consumers might receive. The regulation was ineffective for the reason that no water department wished to admit it wanted the private water in its system. This regulation was therefore rescinded Feb. 8, 1930, and there was developed a better system of cross-connection control, which is described below.

State health departments act as reporting agencies to the United States Public Health Service in recommending certification of water supplies for use on common carriers. Originally, action was based, in each instance, on general procedures laid down by the U.S.P.H.S. in 1914. By 1930 cross-connections had assumed such importance that a special directive was issued by the Surgeon General on Jan. 11, 1930, stating that full certification would not be given a supply if it were cross-connected with another supply which was not under sanitary supervision. Certification could be recommended if the connection were made (1) with another certified, potable public supply; (2) with a potable supply regularly examined by the water department in charge; or (3) with other than potable supplies when equipped with modern backflow protective devices approved by the state department

of public health and under its control. Though this directive dealt only with the supplies used on common carriers, it became plain that the state board would have to adopt the same view with respect to its own water supply permits for all systems and thus the 1919 regulation became unnecessary.

The first application of the new policy of regulating cross-connections was in the case of the East Bay Municipal Utility District, which in 1930 requested a permit to supply water from its new Mokelumne system to the cities on the east shore of San Francisco Bay.

It was known that there were hundreds of private wells in the area and that their development was hazardous. A temporary permit was issued, therefore, with the understanding that a survey of cross-connections with private supplies be made. Upon completion of the survey, the state issued an order that all cross-connections with the public supply be eliminated or, if continued, each one should be protected, either by an overhead feed to a tank or by the use of an approved double check valve installation, the latter to be inspected and tested at intervals of not more than six months. Reports of these tests were to be filed with the state board. Also, no new cross-connections were to be installed between the District system and private water supplies. By December 1932 all known cross-connections had been eliminated or protected and the state issued a full permit to the District with the understanding that the District would continue to enforce the anti-cross-connection order. The program proved to be entirely satisfactory.

During the period from 1933 to 1942 most of the cross-connection elimination or protection work in California was accomplished under the U.S.P.H.S. requirement of 1930. Additional interest was created by the Chicago dysentery epidemic of 1933. Many cities in California henceforth proceeded to control cross-connections by amending their water department regulations. One of the earliest of these was the city water department of Pasadena, which had, in fact, instituted local regulation beginning in 1926. All through the 1930's the movement gained ground, though slowly. The objective was still the backflow protection of the public system against secondary and unsupervised supplies, but with greater emphasis on water piping connections with sewers or sewage. In a few cities this objective led to the inclusion of protection against entry of used or processed waters into the public system. With the advent of war, the cross-connection control program in California assumed new significance.

Waterfront Cross-Connections

Early in 1942 shipyards sprang up in numerous harbors where waters were grossly polluted. It was soon realized that existing piping systems offered numerous means of pumping or drawing harbor water back into drinking water piping of the yard and even into the public system. This tremendous shipbuilding industry brought increased needs for fire systems and auxiliary supplies. The greatly augmented use of cargo docks for ship repair work, the movement of ships between various docks while in port and the necessity of using inexperienced personnel all contributed to the greatly increased hazards of pollution of drinking water lines by harbor water.

The rapid expansion of industrial activity also brought new cross-connec-

tion hazards. Processes connected with cooling and condenser water, organic wastes, metal treatment processes using cadmium, cyanide and other poisonous chemicals were found to be indiscriminately cross-connected with the drinking water systems. Plant expansion without adequate water supply line capacity also increased the hazards of vacuums, producing back-siphonage from plumbing fixtures, process waters and sewers.

These hazards could not be eliminated by protecting only the public system. They called for regulation on the premises as well. Accordingly, the California State Board of Public Health on June 27, 1942, passed a resolution pointing out the increase in fire protection of harbor installations using bay waters through the drinking water piping; the use or re-use of inferior or polluted water supplies in industrial plants and defense industries for various reasons and the increase in negative pressures in water systems from overloading.

The resolution called for protection of all drinking water lines both on the premises and in public systems, and required also the provision of an independent piping system for supplying drinking water on premises where inferior or polluted water could be introduced into the domestic water system. Water piping carrying inferior or polluted water was to be identified by color scheme or other warning signs.

Operators of premises where the means existed, or were contemplated, for using dangerous water for fire protection purposes were required to report to their respective departments of health, water and fire, and to plan and provide for means of protecting the public and employees against resultant dangers.

In spite of this resolution at least seven instances of serious pollution in the harbors occurred within a very few months. These represented a new form of backflow pollution because ships in port connected their fire or sanitary systems by hose to pier hydrants and pumped bay water into the pier drinking water system. In several instances the pollution reached beyond the premises into the public system. Moreover, the resolution was too brief to afford a satisfactory working basis for local officials charged with cross-connection control.

It appeared that much of the pollution caused by connections between the ship fire systems and pier systems was due to the necessity of using untrained and inexperienced personnel. Inasmuch as the Coast Guard has supervision of vessels in port, it was believed that closer supervision by Coast Guard inspectors might prevent the practice of starting fire pumps while shore connections remained.

Accordingly the Captain of the Port for San Francisco Harbor, on Dec. 23, 1942, issued instructions to Security Inspectors requiring that discharge valves on ship pumps be wired shut during those times when lines were connected from the drinking water system on the docks to the ship fire systems. This requirement apparently had some influence in preventing the recurrence of pollution for a time, as no further instances occurred for a period of several months. However, the California Bureau of Sanitary Engineering, water department and health officials concerned agreed that preventing pollution by supervision was subject to the characteristic weaknesses of such types of control, viz., negligence and the human element. Actually time has shown that the directive was in-

adequate and additional cases of pollution from ships followed.

By the spring of 1943 several agencies dealing with cross-connection problems felt that the resolution of June 1942 was too general and that more definite requirements were essential. During the next several months, the Bureau of Sanitary Engineering, in collaboration with various water and health department officers and other interested agencies, prepared six redrafts of proposed new regulations. Each draft was submitted for criticism to the numerous agencies having an interest in the problem. A final meeting on July 9, 1943, before the Director of the State Department of Public Health, was followed by submission of the proposals to the Attorney General and to the State Board of Public Health. The board considered the draft favorably, rescinded its former regulation of June 27, 1942, and adopted the new regulations on Aug. 28, 1943. These are the current state regulations for all cross-connection control. Considerable interest and satisfaction has been shown toward these regulations now in effect in California and they have been widely used.

Requirements of Regulations

It may be pertinent to describe some of the features of the various requirements of these regulations. They are designed to: (1) abate, as rapidly as practicable, existing cross-connections between drinking water systems and unsafe and nonpotable sources of water which cannot be approved; (2) eliminate cross-connections between drinking water systems and other sources of water or process water which jeopardize the safety of the supply; (3) prevent the making of such cross-connections in the future; (4) assure at all times a supply of safe drinking water. The regulations are to be reasonably applied. The term "cross-connection" as used is defined as "any connection between any part of a water system used or intended to supply water for drinking purposes and any other source or kind of water that is not or cannot be approved as reasonably safe and potable for human consumption, whereby water from said unapproved source may be forced or drawn into the drinking water system." Approval lies with the local health authority; the State Department of Public Health, however, reserves final decision.

Backflow Protection

Service connections between the public water system and piping on premises having a dual supply are required to be provided with protection against backflow from the premises into the public system, even though, generally, the higher pressures in the public system would prevent such backflow. The purpose of this requirement is to isolate within the premises contamination or pollution that might occur from cross-connections with the unapproved dual supply on the premises. Complete separation of the systems by feeding the public supply overhead into a tank on the premises is preferred, but where this is not possible, the regulations accept an approved double check valve installation and rather complete specifications are given for an acceptable check valve and an acceptable double check valve installation.

Check Valve Installation

An approved check valve shall seat readily and completely and shall be carefully machined to have free moving parts and assured watertightness. The face and seat for the clapper shall

be of bronze composition or other non-corrodible material which will seat tightly under all prevailing conditions of use. Pins and bushings shall be of bronze or other non-corrodible, non-sticking material, also machined for easy dependable operation.

An approved double check valve installation must contain at least two outside gate valves and two approved check valves with suitable drains and connections available for testing the watertightness of each check valve. While ordinarily water departments would supervise installations and testing of check valves for their own protection, the regulations leave the responsibility with the owner, and prescribe testing for watertightness every three months. The regulations in regard to double check valve installations are not rigid and permit accepting any backflow protection device that is dependable.

Protection Against Fire Systems

Considerable space is devoted to the protection of drinking water systems against fire systems. Here again, complete separation between fire systems utilizing inferior waters and the potable supply is encouraged. However, if this separation is not possible, the public system must be protected against entry of the polluted water into the public supply by an approved double check valve installation. Responsibility for seeing that drinking water lines that become contaminated are sectioned off and faucets posted until precautions are taken to sterilize and flush out all the lines is placed on persons in control. The purpose is to encourage separate fire protection systems. If this is not possible, proper measures are to be taken to protect the health and safety of all personnel concerned.

Protection Against Process Waters

Separation between process water lines and drinking water pipelines shall be secured as rapidly as is practicable. If such separation is not feasible, backflow protection is to be provided on the process water line or lines. Should the process water be corrosive, double check valves are not to be used and some other form of protection is necessary. Sewage pumps must not have priming connections to any drinking water system. Likewise, no cross-connection is allowed between the drinking water system and any piping equipment or tank and any sewage treatment plant.

Because of the numerous cases of pollution by backflow from ships to piers through dock hydrants, the regulations are designed to prevent such pollution from the pier piping system and confines such possibility to the ships themselves, on the theory that protection of the ships lies in federal hands. However, the state has a proper responsibility to protect its citizens on the shore premises. By the regulations, backflow protection is therefore required on the pier piping system beyond the most remote drinking faucet. Attention is directed to the fact that the Bureau of Sanitary Engineering is also asked to certify pier hydrants as watering points for vessels. This requires backflow protection at the pier hydrants. When this is provided, the Bureau feels that the state regulation is fully met, and, in addition, that the vessels are protected against pollution by other vessels.

Since it is unlikely that all inferior water will be removed from premises covered by the regulations, it is required that lines carrying such dangerous waters be posted as a warning to

possible consumers. In premises which also have a separate system of piping for drinking waters, outlets are to be marked to show that they are intended for drinking purposes. The purpose here is to inform both those people concerned with the installation of pipelines, as well as consumers, which lines contain safe and which contain unsafe water.

Another provision states that premises concerned shall designate a water supervisor to be responsible at all times for the laying and use of various pipelines and for the avoidance of cross-connections between them which might permit dangerous or unapproved water to reach the drinking water system. Should contamination or pollution of a drinking water system occur, the local health officer is to be advised promptly by the parties responsible on the premises so that appropriate measures can be taken to overcome the pollution.

A reference to plumbing connections in the regulations points out that ordinary plumbing connection hazards are within local plumbing ordinances and that the state regulations are designed to deal only with those extraordinary situations where sewage may be forced or drawn into the drinking water pipe. Where these conditions exist, dependable backflow protection devices are required. The regulations point out that, since many of the hazards of this kind are due to water supply piping of inadequate size, which produces vacuum conditions when fixtures are flushed or water is drawn from the system in other ways, such inadequate piping should be enlarged wherever possible.

In applying these regulations, the Bureau of Sanitary Engineering has consistently followed a policy of reasonable interpretation, with a timing calculated to keep water departments in sympathy with the program. Particular circumstances of each problem are sought out and weighed in the decision regarding the amount and type of protection required. For example, in supplying backflow protection from pollution by ships, in one community the water department controls all water lines on the pier to the point where ships are supplied and the water is metered at the pier hydrant. In a case of this kind, the water lines on the pier actually constitute a part of the public system. With the water department willing to accept responsibility for preventing cross-connections between drinking water lines and other water lines on the pier available for fire protection, and equipped for the introduction of harbor water through Siamese or pumper connections, the requirement of backflow protection at the street or curb line has been waived. In other communities, water is metered at the street or property line and the water departments will not assume responsibility for the water lines on the customer's premises. Under these conditions, backflow protection of the public system at the property line has been requested in addition to protection at pier hydrants because of the possibility of unauthorized or unknown cross-connections existing on the customer's premises between the pier hydrants and the service connection. This is especially true on those premises having a fire system with provision for introducing polluted water by pumping.

Other installations of pier hydrant backflow protection have called for the advisability of including pressure differential release valves or vacuum relief valves as a part of the backflow protection unit. When a ship's pump

is operated against these units, excessive pressure is developed. If the harbor waters are grossly polluted, local authorities may feel that additional protection is required because of the possibility of check valve failure. In a case of this type, the Sanitary Engineering Bureau can be expected to concur in the request for the additional protection afforded by the pressure differential release valve on good showing that the ordinary double check installation is inadequate.

The same position would be taken in cases where it is demonstrated that vacuums are likely to occur. If the water to be introduced into drinking water lines is likely to be grossly polluted, provision for vacuum relief should be provided.

In the case of sewage it is felt that no backflow protection device, even though equipped with both vacuum relief and pressure differential release devices, could be accepted as reliable on a direct connection between water and sewage. Complete air gap separation is always required.

Procedures recently adopted by the armed services are encouraging and, it is hoped, will prove helpful to state and local agencies in carrying out cross-connection control and elimination in California. Directives have been issued which are designed to reduce the hazard of pollution of public supplies by cross-connections to unsafe waters while vessels are tied up at docks.

The impetus these directives have given to the extensive programs of cross-connection control and elimination now under way in most harbor cities of California, is proving helpful to civilian efforts and it appears safe to state that cross-connection defects are being rapidly eliminated. However, the battle of cross-connection control and elimination must continue beyond the signing of any armistice.

Electrical Pumping Problems

By Louis E. Ayres

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Presented on Sept. 19, 1945, at the Michigan Section Meeting, Grand Rapids, Mich.

THE use of the centrifugal pump in water works practice has been a development of the past 25 years. The first edition of a bulletin on "Service Data" for the centrifugal pump of one of the oldest manufacturers of pumps in this country, a company organized in 1848, is dated 1919. Although centrifugal pumps were then being produced as a commercial product, the bulletin referred to them as a "comparatively new line," with which "customers are not so familiar" as with their "older line of power (triplex) pumps."

Developments in Pumping Equipment

Those whose contacts with water works pumping stations go back 25 years will recall the old horizontal steam-piston, water-plunger type of pump. Many "Holly" compound condensing pumping engines, installed in the 1890's, began to be superseded in the 1920's. Prior to 1925 there were five steam-operated pumps, with a combined capacity of 114 mgd., in the original No. 1 Water Works Park Pumping Station of the city of Detroit. Four of these pumps were of the vertical, triple-expansion type, and the fifth was a vertical, compound, walking-beam type of pumping engine. But in 1925 a contract was placed covering the installation of two electric motor-driven centrifugal pumping units which more than doubled the capacity of this station.

Although the steam pump is not entirely superseded in water works practice, generally speaking the old engines have been replaced by centrifugal pumps, driven by either steam turbines or electric motors. A striking example of the retention of the steam engine is in the No. 2 Pumping Station at Water Works Park, Detroit, where much water is still pumped by large, vertical, triple-expansion engines. And one may surmise that these engines will remain in service for years to come.

The old steam pump was ideally adapted for water works pumping. It was reliable, flexible and efficient over a wide range of operating requirements. It never wore out; and although its maintenance was sometimes neglected and considerable "slip" occurred, it could be put back into excellent shape by the typical plant superintendent of that day. When the fire department needed higher pressures, the pumping engine was speeded up. Fires were fought by direct pressures, with 100 lb. or more available at the hydrant. Fire pumpers were not then necessary. The higher pressures may have caused broken mains or leaks in house plumbing, but most of the other requirements of a direct-pressure system were well met by such equipment.

However, towns grew and water demands increased. Many communities were faced with the need for additional pumping capacity.

In the larger towns, the steam-turbine-driven centrifugal pump became available. It, too, could vary its speed to meet the changing demands in pressure and quantity, but only within the limits of the characteristics of the centrifugal pump. It was not possible, however, to increase pressures from 50 up to 100 lb. or more to fight fire. Either special high-head fire pumps or two centrifugals in series were necessary to meet such a requirement; and the fire pumper at the hydrant took over this service.

There are several illustrations in Michigan of steam-turbine-driven centrifugal pumps, as, for example, at Port Huron, Flint, Jackson and Bay City, the last containing both reciprocating and steam-turbine driven equipment.

Port Huron furnishes a typical case history of the development of pumping equipment. The present pumping station bears the date 1872. It was enlarged in 1894. In 1915 we read that the equipment consisted of two Holly-Gaskill horizontal compound condensing engines, one of 5-mgd. and one of 12-mgd. capacity, furnished with steam from six 5-ft. diameter boilers, 16 ft. long, each having 64 3½-in. fire tubes. Four boilers were ordinarily in service at a time and the pressure carried was usually 65 lb. In 1921 two new horizontal water tube boilers for 165-lb. pressure were installed; and the larger Holly pump was operated at 100 lb. and delivered water at from 50- to 90-lb. pressure. In 1924 two steam-turbine-driven centrifugal pumps were installed and in 1936 a third went into service. Today, faced with the alternative of replacing its 1921 boiler installation or electrification, the city has decided to replace the steam-turbine-driven equipment with motor-driven centrifugals, supplemented with elevated storage.

The higher speeds of steam turbines as compared to centrifugal pump speeds require the use of reducing gears; and the units are relatively expensive. Also the steam turbine requires a boiler plant with its attendant first cost and operating expense. Unless the steam installation is relatively large it may not be able to compete with motor-driven equipment at the power rates frequently available from large electric systems.

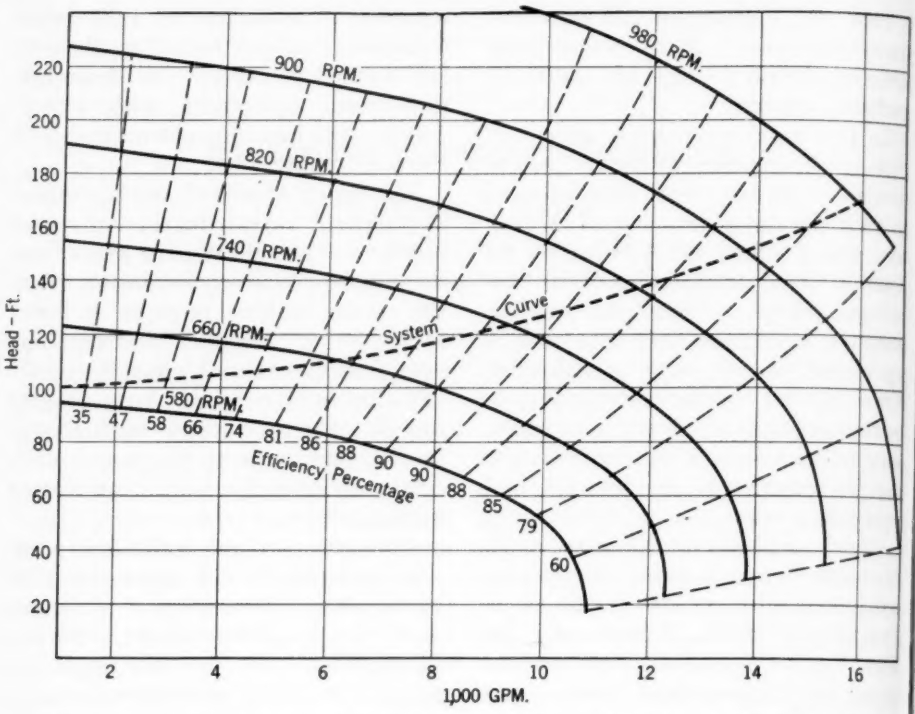
The motor-driven centrifugal pump has displaced the old steam pump because it was only a fraction of the size and could be purchased for a fraction of the cost. But the centrifugal had deficiencies in its application to water works pumping; and numerous methods for the approximate correction of these deficiencies have engaged the attention of engineers and operators ever since.

Deficiencies of Motor-Driven Centrifugal Pumps

1. The motor-driven centrifugal pump is dependent on the continuity of its supply of electric energy. This supply is bound to be interrupted, for long or short periods, if the source of power is removed from the motor terminals by any appreciable transmission distance.

2. The head-capacity characteristic of the centrifugal pump is not well adapted to water works pumping.

What is often called the "system curve" of a water works, which is a plotting of the relationship of the head required of the pumps to the quantity



System Curve, Showing Relationship of Pump Heads to Quantity of Water Required

of water required, invariably shows an increase in head for increased demand (see figure). The centrifugal pump, on the other hand, operating at constant speed, decreases its delivery with an increase in head. Obviously, the pump can operate only at the intersection of its head capacity curve with the system curve; and this operating point may be other than the best efficiency point for the pump. If the quantity that the pump can deliver at a given head is less than the system demand, the pressure falls, or conversely, until an equilibrium is established.

3. If a correction is sought by a change in speed of the pump, the basic laws, governing change of speed, are not adapted to the system curve.

When the speed of a centrifugal pump is changed a new set of characteristic curves of quantity, head and power prevails. Considering corresponding points on two sets of curves, the quantity varies as the speed, the head varies as the square of the speed and the power as the cube of the speed.

These laws mean, for example, that if the speed is reduced by 10 per cent the head should be reduced by 19 per cent and the power by 27.1 per cent, if the pump is to continue to operate at the corresponding points on the new curves. Obviously, the above relationships do not prevail when one changes speed on any particular water system. The pump still must operate at the intersection of its new head-capacity curve with the system curve. But the typical system curve is likely

to require a 25 per cent reduction in quantity and only a 10 per cent reduction in head, which is practically the reverse of the relationship governing the centrifugal pump.

The application of variable speed to the centrifugal pump is not, therefore, an ideal solution in water works pumping. It is just one of several means that may be employed to maintain operation along any desired system curve.

Methods Used to Correct Deficiencies

The objectives desired are security and continuity of service, with adequate pressures for all rates of water demand and the best possible efficiency of operation.

To provide security and continuity of service the electric energy should be generated in the same building with the pumps. This is the situation, for example, at the Springwells plant in Detroit. With an outside source of energy one may provide: (a) duplicate power services, (b) standby units, diesel or gas engine driven and (c) elevated storage.

Duplicate services may assure a reasonable continuity of supply if the services are short and are from a highly reliable substation or from a generating plant. Standby units take time to place in service. They are of advantage only if the time during which the electric supply may be out is likely to exceed the time it would take to place the standby unit in operation. Both of these plans need to be supplemented by some elevated storage if uninterrupted service is to be assured.

Elevated Storage

The need for elevated storage in flat country without hills led to the improvement and development of the elevated tank. It is not an unmixed blessing. Stored water in a reservoir on a hill is much to be preferred. Tanks are objected to in residential sections and it is sometimes not too easy to find satisfactory locations. But the appearance of the tank has been greatly improved in recent years. Twenty years ago it was an ugly structure; today types are available that sometimes make a pleasing addition to a park setting. Tanks holding 1 mil. gal. of water, within a vertical range of 25 ft. or less, are not rare, and much larger capacities are available.

Elevated stored water may serve one or more of several functions. It may serve to equalize the variations in demand in relation to a nearly constant rate of pumpage, or it may alternate with the pumps in being the community's source of supply in intermittent operation. Concurrently with the above functions it should provide the emergency supply for fire protection, and for general use during an outage of electric energy. Also, at the terminal of long feeder mains elevated storage can become a supplementary source of supply to relieve the main pumping station during peak demands and to maintain adequate pressures in outlying areas. Tanks are also useful on long lines to reduce surges from heavy and sudden drafts by large customers.

Obviously, not all of the possible services can be rendered by the same tank. If a tank "floats" on the line to "equalize" pumping rates, its stored water is not likely to be sufficiently conserved to provide an emergency supply, particularly if its location is remote from the pumping station. If water is needed only during peak hours to maintain pressures, certain controls

over the tanks must be exercised. The stored water must be held in storage until needed and then discharged, or some of the anticipated benefits of storage will be lost. Although elevated storage is often a requirement in a water system supplied by motor-driven pumps, its location, size and control are important considerations if over-all efficiency, satisfactory pressure and continuity of service are to be secured.

Throttled Valves

The throttling of pumps by closing the discharge valve is probably one of the most common methods of exercising control over pressures and for moderate reductions in head it is probably the best method. Some towns allow the pressures to fluctuate as the demand varies. This is equivalent to throttling as far as efficiency is concerned, and the service rendered is less satisfactory.

Throttling with the ordinary gate valve is hard on the valve; but plug or cone valves will stand up under such service. An extreme illustration of throttling with cone valves is found in the Modern Avenue booster station of the Detroit water system. The function of this station is to boost pressures in the northern parts of the metropolitan area during hours of maximum hot weather demand by pumping into the feeder mains from a storage reservoir. The pressure and quantity range is large but the time of operation short. The original pumps were rated at 40 mgd. at 245-ft. head. During the first season they were operated much of the time around 50 lb. (equals 115 ft.) and the difference in head between that produced by the pump and that in the mains, about 130 ft., was dissipated through a 24-in. cone valve. There was no apparent vibration of this valve and no observable wear over a short period of operation. By the next season the rated head of these pumps had been reduced to 180 ft., so that the amount of throttling now required is much less, but still considerable.

Multiplicity of Units

A system head curve can be closely approximated by several units of different ratings. Such an arrangement is particularly applicable to larger plants, and the combination of one variable speed unit to two or three constant speed units often makes a satisfactory installation.

The Springwells plant in Detroit is a good example of a multiplicity of motor-driven centrifugal pumps, both constant speed and variable speed, capable of meeting a wide range in station pressures with good efficiency throughout. In the original studies a system curve on the intermediate service was projected to cover a range in head from about 110 ft. to 170 ft., with a range in quantity delivered from 40 to 130 mgd.; and on the high service the anticipated range of head was from about 170 to 240 ft., with a range in delivery from 35 to 140 mgd. Each system was to have six motor-driven centrifugals of varying ratings, two variable speed units and four at constant speed. An application of the pump characteristics showed the possibility of applying combinations of pumps to the system curves and maintaining an over-all efficiency of between 80 and 85 per cent. It is interesting to note that, according to the 1944 Annual Report of the Department of Water Supply, the average annual operating efficiency of the intermediate service was 84.18 per cent, and of the high service 80.28 per cent.

Variable Speed Operation

An extreme example of the application of a variable speed unit is in the case of the booster pumps at the Ann Arbor Water Works softening plant. In this instance two 3,500-gpm. variable speed centrifugals discharge into two 16-in. mains which carry peak load water to both the east and west sides of the city. The distribution pressures on the east side are transmitted to the plant by telephone wires leading to a recording gage. By observation of a chart the operator can tell when pressures are falling below a desirable minimum and when they do he starts a pumping unit. At the start the amounts delivered to either main may be very small and the head negligible. At 875 rpm. the pumps operate at 30- to 35-ft. head; at 1,315 rpm. around 80-ft. head; and at 1,750 rpm. from 130- to 145-ft. head. The delivery, of course, depends upon the friction of the discharge lines with any given flow, but the quantity delivered through a 16-in. main may vary from practically zero to a rate of 5 mgd. or more.

There are really only three methods available at present for varying the speed of a centrifugal pump. An excellent discussion of both the developed and prospective methods is presented by C. A. Richardson [Jour. A.W.W.A., 36: 1315 (1944)].

The first method uses the steam turbine, usually driving the pump through reducing gears.

The second method is the application of the variable speed, wound rotor or slip-ring motor, directly connected to the pump.

The third method, more recently developed, is the use of a synchronous motor connected to the pump through a variable speed hydraulic coupling.

A fourth method uses a direct current motor with speed control. It would be ideal if the source of power were direct current, but with alternating current, requiring a rectifier or motor-generator set, the cost is too high for normal application.

A possible fifth method involves the application of a magnetic coupling instead of a hydraulic coupling between the synchronous motor and the pump. But large-size magnetic couplings are yet to be developed as a commercial product. It should be added that the practice of throttling the discharge valve produces the effect of variable speed operation.

The variable speed wound rotor or slip-ring motor has close competition in the newer synchronous motor with the variable speed hydraulic coupling, in so far as initial cost and over-all efficiency are concerned. One will not be too far wrong in assuming that either of these types will cost about 50 per cent more than an equivalent constant speed unit, although if throttling is accomplished in the constant speed unit by a cone valve or equal, this difference in cost will be reduced. The efficiency of the slip-ring motor decreases in proportion to the reduction in speed, and the decrease in efficiency with the hydraulic coupling is not far different. The coupling has an initial slip, but this slip is substantially offset by the higher efficiency of the synchronous motor as compared with the slip-ring motor.

The slip-ring motor installation is the standard drive; the variable speed hydraulic coupling is a relatively new development. The speeds of the slip-ring motor are determined by the steps of the controller. In the variable speed hydraulic coupling the power is transmitted "by the automatic circulation of

oil between radial passages formed in the two rotating elements" called a runner and impeller; it provides what one manufacturer calls "split revolution" control over a wide range of speeds. Beyond this point the comparison would enter into details, electrical and mechanical. The choice for any particular installation would warrant careful study.

Other Considerations

Besides the questions above discussed, which enter into the problem of selecting new motor-driven equipment, there are others of some importance.

In advertising for centrifugal pumps the specifications should be carefully prepared. The field of pump manufacturing is a large one and the competition is keen. Some control over efficiency is desirable. When a pump of a given rating is requested, not every pump manufacturer can fit that rating to the best advantage. Some bidder may submit a proposal on a pump satisfactory in every mechanical respect but having its point of best efficiency at the right or left of the rated point. In water works pumping against variable head, a pump with a steeper head characteristic curve may be preferred to one with a flatter curve. Generally it is desirable to require certified shop tests before shipment, and witnessed tests on important units, with a suitable provision in the specifications to protect the purchaser in the event of the failure of the shop tests to meet the guarantees.

The setting of a centrifugal pump deserves consideration. It is not a self-priming device; if the suction water is below the eye of the impeller the pump requires priming at starting. It is always desirable to keep the suction head to a minimum, and eliminate it if possible. With suction lift the head capacity characteristic of a centrifugal breaks sharply to the right of the rated head point, while without suction lift the head falls off gradually with increase in quantity.

But the setting of centrifugal pumps and motors in pits below suction water in order to avoid suction lift is not good water works practice. Piping and connections do break; and a flooded pit, including flooded motors, is likely to put the plant out of service for a considerable period. The usual answer is a vertical setting for the units.

Surge in pumping stations, caused by the sudden stopping of a unit or the complete outage accompanying a power failure, particularly with long suction or discharge lines, is too important to neglect. It can be easily provided for with surge relief valves. In the Detroit booster station the surge provision consists of two 16-in. cross-connections between discharge and suction lines, controlled by automatic relief valves.

In the operation of centrifugal pumps it is worth while to run periodical field tests and inspections, to determine the wear of rings or other parts. Records of the water pumped, the heads pumped against, and the kilowatt hours consumed are helpful if one aims to operate at the best possible efficiency.

The pumping of water for water works service is not a simple matter. It has many aspects, varying in different communities, which deserve careful study and planning and conscientious operation if efficiency and good service are to be attained.

Problems With Iron in Deep Well Supplies

By E. M. Grime

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Presented on Sept. 11, 1945, at the Minnesota Section Regional Meeting, Mankato, Minn.

WHEN seeking water for either a locomotive or a domestic supply it is desirable to find one which is reasonably soft and comparatively low in total dissolved solids content. At many locations a much more important factor to consider is that of iron, which occurs in the soluble ferrous form and which may prove more detrimental than either excessive hardness or dissolved solids. The amount of iron may vary from as high as 6–8 ppm. to below the 0.3 tolerance prescribed by the U.S.P.H.S. Drinking Water Standards.

Ordinarily, the occurrence of iron in water to be used for evaporating purposes is not serious if in small quantities which will not interfere with water conditioning processes. However, if large quantities of an iron algae aggregation known as *Crenothrix* are passed into a steam boiler, foaming trouble may be caused by the liberation of oil during destruction of the *Crenothrix* at high temperatures.

The effects of iron salts may be quite different under dissimilar conditions, but in all cases will depend on the volume of water required and the amount of iron present and, to some extent, on the method of pumping and the design of the well. While possibly no two sets of conditions are exactly the same, the three examples cited herein are typical of the author's experience in a number of cases.

Deep Well in North Dakota

A simple case is that of a 20-in. well, 160 ft. deep, which draws water from a glacial drift deposit in central North Dakota. Because of the occurrence of extremely fine sand, which it is impracticable to hold back but which is sufficient to cause excessive wear on a turbine pump, an air lift is used to raise the water into a surface reservoir where the sand can be settled out and the clear water then pumped through the softening plant. The pumping rate is 12,000 gph. and the demand between 120,000 and 150,000 gpd. A cycle of twelve analyses of this water shows a variation of from 0.4 to 1.5 ppm., and an average of 1.06 ppm. iron. It was not known if the iron naturally existed in the ground water or if it was the result of corrosion of the well casing, eduction pipe and air line, but a series of tests made after the water had been standing for a time in the well and again after it had been pumped for some hours indicated that the iron existed in the ferrous form in the natural water as $Fe(HCO_3)_2$, which changes finally to the form Fe_2O_3, or hematite.

In this case there were no iron-consuming or sulfate-splitting bacteria in the well and the reddish-brown sludge which formed on the eduction pipe to a thickness of 1 in. or more in a period of about ten years is mostly ordinary

precipitated iron in the ferric form. It can be removed completely by treatment with hydrochloric acid and the well restored to its original capacity. As the air is delivered at the point where the water enters the eduction pipe, corrosion at that location is naturally excessive and wearing away of the pipe, especially within a few feet of this air outlet, requires pipe renewal at about ten-year intervals.

Deep Well in Washington

The next case is that of a well furnishing water not only for locomotive use but also for domestic purposes in the local community. It is located on the eastern slope of the Cascade Mountains in Washington. The formation here is entirely glacial drift, largely consisting of fine sand mixed with granite boulders 3 to 8 in. in size. The well is 12 in. in diameter and 120 ft. deep, and is cased with steel pipe which is perforated between the 95- and 105-ft. levels with slots $\frac{3}{8}$ in. × $\frac{3}{4}$ in.

When the well was completed, the water had a pH of 7.8, and the analysis was as follows:

	ppm.		*ppm.*
$CaCO_3$	54.7	SiO_2	28.1
$MgCO_3$	41.0	NaCl	5.1
Na_2SO_4	0.0	Iron	1.2
Total Alkalinity	126.5	Total Dissolved Solids	145.4

When the well was first put into service the water was crystal clear and there was no odor when either hot or cold. After it had been in use for about only two months customers complained of a disagreeable taste and that the water became cloudy after standing, making it unfit for laundry purposes. Investigation showed that this was another case of iron trouble and practically every known method was tried for precipitation and removal of the iron as the water was pumped into the 100,000-gal. storage tank. All methods failed, however, and complaints continued as the disagreeable taste became more pronounced and as a hydrogen sulfide odor developed, especially when the water was heated. Due to an increasingly heavy demand for water it became necessary to operate the pump at maximum capacity for long hours, depleting the water stratum to such an extent that frequently the water dropped to a point below the pumping level and the pump drew air, thus creating intermittent operation.

About this time a stringy yellowish-red formation, about 3 in. thick, was found floating on the water surface in the storage tank, and a reddish-brown slime was found in the eduction pipe. Analysis of these materials showed 450,000 bacteria per ml. (3,100 were of the spore-bearing type), sulfate-reducing bacteria to the extent of 10 per ml., abundant iron bacteria of the *Crenothrix* variety, and a few algae. This indicated the desirability of chlorination. A gas-type chlorinator was installed, using a rubber hose for the delivery of hypochlorous acid to a point in the well close to where the water enters the pump.

This chlorine installation quickly solved the iron trouble and in a very brief time eliminated all complaints of taste and odor. The water became quite clear and had no odor even when heated, and the bacterial growth at the top of the storage tank completely disappeared. An improvement was noticed after the first two days of operation of the chlorinator. A 0.2 ppm. chlorine residual was maintained in the distribution system, and it was not long before stains on the plumbing fixtures, which apparently had been caused

by the bacteria cementing iron oxide to the porcelain, completely disappeared. Iron still remains in the water in about the same quantity, but presumably is now converted to the ferric chloride form which is soluble and readily washes off the porcelain.

Deep Well on Pacific Coast

The third and most interesting case is that of a well on the Pacific Coast in Washington where the iron content is only 0.2 ppm.—less than the standard requirement for an acceptable sanitary water.

This well was constructed in 1934 but was not put into service until August 1943. It is 16 in. in diameter and has a total depth of 63 ft. It is constructed with a 26-in. outer casing extending down to the 38-ft. level, with concrete filling to that depth between the 16- and 26-in. casings. In the space below 38 ft. and extending to the 63-ft. level is selected gravel filling. As in the previous cases, this also is in a glacial drift formation where the gravel is coarse and comparatively free from sand.

When the well was first put into operation under normal head conditions the production was 440 gpm., but by June 1944, with no change in the static water level, production had dropped to an average of 325 gpm. with the water standing only 10 ft. over the pump inlet, and it was evident that there was something wrong. Our first thought was that the slotted pipe openings had become incrusted with iron and calcium or magnesium carbonate and hence cleaning with inhibited hydrochloric acid was tried. Two thousand five hundred pounds of inhibited acid was poured into the well and allowed to stand there for a period of eighteen hours. The results were completely disappointing as pumping trials showed no increase in production. After the pipe was disconnected a soft reddish-brown incrustation, about $\frac{1}{8}$ in. thick, was found on the inside, and there was also a small amount of what appeared to be *Crenothrix* formation floating in the storage tank. In addition, it was found that after the well was back-flushed from the storage tank the static level could be raised several feet above the normal level, indicating clogging of the slots or the adjacent formation. This might have been caused by the floating *Crenothrix*, which is a stringy material which will admit the water, but will plug the slots or the formation if carried back by a water flow in the reverse direction. Whatever the identity of the plugging material, it was thought that heat might break it down, and so the next attempt made was to heat the water in the well, holding it at boiling temperature for five hours. This again did not make the slightest improvement and by November 16 the capacity of the well had dropped to 290 gpm.

Field experiments at this time indicated that the sludge and other iron formation were insoluble in either nitric or hydrochloric acid in the cold. With hot nitric acid the pipe-incrusting material was readily soluble but the bacteria remained practically insoluble. Hot HCl was less effective but iron oxide would go into solution by agitation in this acid. Gravimetric examination of the sludge found in the pipe showed the following percentages:

	%		%
SiO_2	5.8	CaO	11.1
P_2O_5	4.0	CO_2	4.0
Fe_2O_3	51.0	Loss on ignition	23.5

Microbiological analysis of the sludge showed that sulfate-reducing bacteria

—more than 100 per ml. iron bacteria (*Crenothrix*)—were abundant, iron and carbonate were present, and algae (green) were present and suggestive of filaments. Experiments made with chlorine gas showed that, although it would stop growth of the bacteria, it would not loosen algae sludge which had already been formed.

In view of the above data it was decided to make use of a surge plunger to loosen up and remove incrustation from the face of the perforated casing and, if possible, to remove that which might have accumulated within the perforations and in the gravel formation back of the casing. It was also probable that small particles of gravel might have become cemented together against the pipe or in the aquifer farther back, thus preventing free flow. The plunger consisted of a laminated wood disc 6 in. in diameter, about ¼ in. smaller than that of the well casing. Attached to this was a well drilling rod, heavily weighted so as to cause the plunger to drop rapidly and push the liquid back through the perforations and out into the formation as quickly as possible. The plunger was rapidly moved up and down by means of a double drum gasoline hoist. Thirty-minute surging intervals were allowed before the loosened material was bailed out, and before each surging operation there was added in the well casing 600 lb. of inhibited hydrochloric acid and 10 lb. of ammonium fluoride. The hydrofluoric acid thus formed was intended to dissolve calcium or magnesium silicate which might be cementing parts of the gravel formation into an impervious mass.

After each surging operation all gravel and sand brought into the well was removed by bailing. The liquid had a deep reddish-brown appearance. Gravimetric analysis of this and its residue gave the following percentages:

	%		%
SiO_2	36.5	Al_2O_3	20.6
Fe_2O_3	18.0	CO_2	3.3
CaO	2.0	Loss on ignition	13.2
MgO	5.0		

After four 30-minute surgings the water was practically clear and only a small amount of clean gravel was obtained. Microbiological analysis after this showed remarkable improvement, as indicated by the following analysis: Sulfate-reducing bacteria, 1 to 10 per ml.; iron bacteria (*Crenothrix*), few; algae, none.

Upon completion of this surging, the well production was tested for comparison with previous tests, particularly those made in November 1944. While the discharge head varies from 70 to 100 ft., the normal discharge head is about 90 ft. In Fig. 1, it is shown that at this head, the production has been increased from 290, as it was on November 16, to 400 gpm., or 38 per cent, which is somewhat better than when the well was first placed in operation Until this well cleaning was undertaken the static

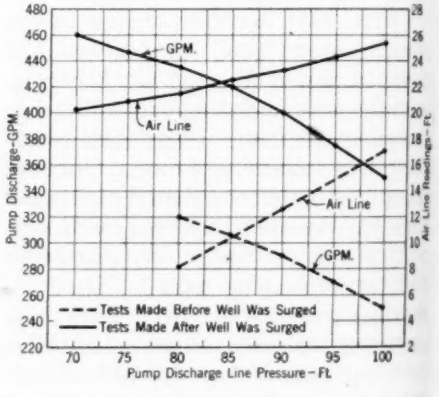

FIG. 1. Increases in Well Production Following Surging

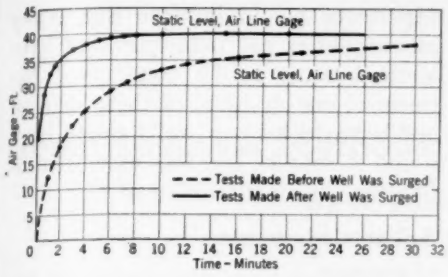
Static Level, Air Line Gage
Static Level, Air Line Gage
Tests Made Before Well Was Surged
Tests Made After Well Was Surged
Air Gage - Ft.
Time - Minutes
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
5 10 15 20 25 30 35 40 45

FIG. 2. Static Water Levels as Shown on Air Line Gage Before and After Surging

water level would not rise above 38 ft., but, as may be noted from Fig. 2, it now comes up to the 40-ft. level within eleven minutes, as compared with the original curve which shows a period of 30 minutes to rise to the 38-ft. level. Most important of all is the fact that under the highest rate of pumping the water level does not drop closer than within 20 ft. from the pump inlet. Where algae growth requiring oxygen is present it is very desirable not to permit the water to drop lower than about 15 ft. from the pump inlet.

Experiments with the use and then the non-use of high-rate chlorination, over about two and one-half months, show that, while chlorination will prevent the formation of new incrustation, it will not appreciably affect that already formed. It was also learned that in this case, within a period of two and one-half months without chlorine, incrustation consisting of iron products and algae would accumulate to a thickness of $\frac{1}{4}$ in. Obviously, if permitted, this would soon cause serious clogging of all connecting pipelines, necessitating cleaning by mechanical means. There would also be heavy sludge accumulation in the storage tanks, which would be detrimental to locomotive operation because of foaming tendencies caused by insoluble materials in the feedwater and by the vegetable oils released.

Since cleaning the well, chlorination, by means of a visible-type vacuum chlorinator with the hypochlorous acid delivered to a point near the pump inlet, has been used at all times when the pump is in operation. So far as can be determined, this is preventing new growth of incrustation formed by the iron-consuming bacteria and their co-partners, the sulfate-splitting bacteria, which seem to develop whenever *Crenothrix* runs short of the required oxygen supply. In this particular instance there was very little hydrogen sulfide odor, probably indicating that in this comparatively open water-bearing formation there was almost sufficient oxygen to support the *Crenothrix* with but little assistance from the sulfate-splitting bacteria, which seem to be responsible for bad taste and odor. Before the well was surged there had been times when heavy and long-continued pumping drew air down with the water nearly to the pump inlet, thus fully supplying the oxygen necessary for the growth of *Crenothrix*.

The 2-ft. rise of the static water level and the quicker response after the water has been drawn down seem to indicate that much of the improvement in flow is due to the opening up of the formation adjacent to the casing by the disturbance caused by flushing with acid rather than to the cleaning of the perforations. Since it is not uncommon to have filters and base-exchange softener units seriously affected by microbiological deposits, it seems probable that the same effect may readily take place in an aquifer adjacent to a well casing when the proper combination of the filamentous group of iron-consuming bacteria and the sulfate

splitters, known as *Beggiatoa alba,* are present.

Conclusions

It seems clear that whenever a deep well is supplied from a water source containing iron in solution, biological analyses should be secured, and if bacteria of the kinds referred to in this paper are found, steps should be taken to destroy them at the source, in order to avoid trouble from decreased production, incrustation of pipelines, disagreeable odors and taste, corrosion and similar difficulties. The author's experience would indicate that many municipalities and industries that have allowed wells to be condemned because of one or more of these defects, and have drilled new wells, might have found it simpler and less expensive to provide chlorination instead.

Acknowledgments

For information concerning the behavior of aerobic and anaerobic types of bacteria, the author is indebted to the investigations of A. H. Thomas, R. F. Hadley, A. E. Griffin, E. P. Partridge, F. N. Speller, et al.

Good Business Methods in the Small Water Plant

By R. Gordon Yaxley

Supt., Board of Water Comrs., Waterford, N.Y.

A contribution to the Journal

THE village of Waterford, N.Y., is located at the head of the tidewater of the Hudson River, and the "Great Military Road," built by the English in the early days to provide access to Crown Point, Ticonderoga and other northern forts, passed through its environs. Settled before the Revolutionary War, it grew very rapidly after peace came and settlement of the north country began. As a transfer point between wagon and boat it became an important shipping center. When the state canal system was built in the early part of the last century, Waterford was bypassed in favor of terminals farther down the river. It is today the oldest incorporated village in the state and has a population of about 3,000.

Waterford Water Supply

The first public water supply, other than the old hand pumps located at various street corners, was installed by a private company in 1885. Indications are that it was one of those high-pressure promotion jobs that were frequent in those days. It is known that it was built as cheaply as possible and mortgaged to the limit and the local stockholders were left holding the bag. Water was obtained from the Hudson River which was heavily polluted with both industrial and domestic wastes. This water, untreated in any manner, continued to be the only supply until 1912. In that year the town started action to obtain a satisfactory substitute for the mixture they were receiving.

The Board of Commissioners

By an act of the state legislature (1), a board of five commissioners was formed, which was empowered to purchase the old system or build a new one. This special law, in the author's opinion, produced the success that has accompanied public ownership of this small utility. While the act contains many paragraphs taken from the old "town law" regarding the formation of water districts and their operation, it has this important difference—the commissioners are appointed by the town supervisor, not elected by the people, one each year for a term of five years. This places the responsibility for the personnel of the board squarely up to one person, not leaving it to the whim of a political group. As a result of this proviso, the board has always consisted of a non-partisan group of representative businessmen serving long terms without compensation. Another important feature is that the board has jurisdiction over the whole township, so that extensions can be made without the question of district boundaries being raised. It has also proven convenient in answering questions raised by the New York State Board of Water

Supply and Control when new subdivisions have opened up.

Acquisition of the Plant

The newly-formed board, after a careful investigation of sources of supply, recommended the purchase of the old private system, and, after a hot special election in which some opponents claimed voters were brought from the graveyard, its findings were approved. Plans and specifications were then prepared for a modern mechanical filter plant of 2-mgd. capacity, construction of which was completed and the plant placed in operation in the early spring of 1915.

The old system consisted of about 10½ mi. of mains, two steel standpipes of a total capacity of about 500,000 gal.; a pumping station containing two small boilers and two Worthington duplex steam pumps, one of 1-mgd. and one of 1½-mgd. capacity; and a small amount of real estate. The price paid for the above was $92,500.

The cost of the filter plant, which included a new boiler house, work shop and office building, new boilers, new engine-driven low-lift pumps and the rebuilding of the two Worthington pumps, was $47,500. There was thus a total debt of $140,000 which was covered by serial bonds, payable at the rate of $4,000 per year with interest at 5 per cent. There now remains $12,000 of this original plant debt.

Major Improvements

Operating costs reached a prohibitive figure in 1921 and the plant was completely electrified, using purchased power. The cost of this renovation was approximately $16,500 and was paid from earnings and an increase in the tax rate. The reduction in costs amounted to over 33 per cent per year on the investment.

A spray nozzle-type aerator was constructed in 1926 at a cost of $2,775, paid from earnings (2).

Two steel standpipes, with a total capacity of 0.666 mil.gal., were constructed in 1927 and paid for by bond issue of $24,000 in 4.25 per cent serial bonds, payable at a rate of $1,000 per year.

A new high-pressure pumping unit was installed in 1930 at a cost of $1,500, paid from earnings.

In 1934–1935, 2 mi. of 12-in. cast-iron pipe, sixteen hydrants, necessary valves, etc., were installed in a newly-formed fire prevention district. This was a WPA project and cost the community $24,000 in 3.2 per cent serial bonds, payable at a rate of $1,000 per year. One half of these bonds are a charge against the district and the balance was assumed by the town at large. There was some criticism because such large pipe was installed for the small load in sight at the time. Since then a large chain store outfit has built a warehouse with over 80,000 sq.ft. of floor space, the General Electric Co. has purchased 60 acres and a nationally-known concern furnishing material for the auto industry has 20 acres. Construction on each site will start as soon as conditions permit. The main reason for their selection of this location was the fact that a public water supply was available in sufficient quantity for fire protection.

Finance

The board of commissioners is an independent corporate body having complete control of all funds and property belonging to the water works. It is responsible for keeping the plant in proper repair and supplying the com-

munity with a safe and ample supply, for both public and private use, at all times. It can make such extensions to the distribution system as it sees fit, provided that the returns from new consumers pay at least 5 per cent on the investment. This limitation does not apply to work that would be classed as a general improvement to the system, such as the addition of a feeder main or the replacement of old mains that have outlived their usefulness. One exception to the above is the provision that any single project that costs over $5,000 must be approved by special election. However, this clause has always been interpreted as applying to work that required bond issues, not to replacements or repairs paid for from available funds. In the author's opinion one rather undesirable clause is that which provides that all funds in excess of those required for general use, as mentioned above, must be turned over to the township to apply on water works bonds, which are a town obligation, not a utility one, such as is common in some states. This provision prevents building up a surplus for the future, but fortunately has never been too strictly enforced.

All services are installed and maintained by the property owner, the board having complete jurisdiction over choice of material, size, location, etc. Meters are owned by the property owner, but repaired by the board without charge, except for damage from frost, hot water or malicious damage. The make and style of meters are specified by the board. All bills are sent to the owner of the property served; the board has no dealing with tenants. All water rents and similar charges are a lien on the property served, and, if over six months in arrears are placed on the town tax roll and collected with the regular tax, the town officials return the money thus collected to the board. Thus there are no delinquent accounts, and the use of the shut-off key for collection purposes is not necessary.

Meters are read every three months, the town being divided into three districts. One is covered each month, thus evening up meter reading, office work and receipts—an ideal arrangement for a small city. Water bills are made out on regular government post cards. There are stubs which are detached for the office record when paid and the cards show previous and present meter readings, gallons of water used, rate per 1,000 gal. and total amounts of the bills. Bills with unpaid previous quarters are made out on plain white cards printed in red and are mailed in sealed envelopes. Postal regulations prohibit showing overdue accounts on postal cards. One clerk, who is also assistant treasurer, the regular treasurer being a member of the board, does all the bookkeeping, acts as cashier and pays all accounts except for the actual signing of checks. Both treasurer and assistant are under surety company bonds paid for by the board.

Water accounts are carried on loose-leaf ledgers, a page for each meter. Receipts and disbursements are posted in a cash book showing source and distribution under major account headings. These are then entered in separate loose-leaf books, one for each major sub-division.

Receipts are deposited in a local bank which is a legal depository for municipal funds and all bills are paid by check except for a few small items paid from petty cash. The books are audited each year by a representative of the bureau of municipal accounts of

the state comptroller's office, a regular procedure in New York State.

Personnel and Operation

The entire crew consists of a superintendent; a clerk in the office; a meter reader who also acts as foreman on repair jobs, etc., and as relief operator for the pumping station and filter plant; a regular plant operator; and a laborer. To illustrate one advantage of the nonpartisan, business-type of board membership, the present superintendent has been on the job for 24 years, the plant operator for over 30 years, the clerk for nearly 30 years and the meter reader for eleven years. The latter replaced a plant operator who served 49 years. Only one plant operator is required as the station operates only about seven hours per day. The regular payroll is a little over $700 per month.

The superintendent is in complete charge of the entire outfit and is held responsible for its operation and general condition. He purchases all supplies and equipment, designs and installs all extensions, etc. Not a dollar of water department funds has been paid to a contractor, except for the installation and painting of the standpipes, in over 20 years. The same is true of engineering fees, the only fee being that paid to a local engineer to make out the papers for a WPA job, as regulations required a licensed engineer's signature. Details of the project were furnished by the office. The superintendent is in effect a general manager answering to the board of directors.

The author is firmly convinced that practically every smaller water plant that is in good financial and physical condition will be found to be in charge of some man who combines the talents of business executive, engineer, mechanic, common laborer and public relations expert.

The present manager came on the job in 1921 to install the electric pumping equipment and when this and other urgent work was finished, a general survey of the distribution system was started. Blowoffs were found partly open, the idea having been that it would keep dead ends, etc., fresh. Many services were found leaking. Some industries were being billed on a flat rate basis or were being supplied through meters that were unsuitable or in bad condition. Street valves had not been checked in years and location records were nonexistent. The situation was, in general, what would be expected after years of neglect. After correction of the above features and the adoption of a 100 per cent metering program there was a remarkable change (3). A strict inspection program was initiated and has been maintained through the years. Valves and hydrants are tested with the aquaphone and operated twice a year and the meter reader checks every service with the aquaphone at each visit. A close watch is kept on recording pressure gage charts, especially in the early Sunday morning hours when the industrial load is off. With a storage capacity of 17,000 gal. per ft. the result of a single service leak of any magnitude can be detected on the 12-in. chart.

The satisfied customer is the greatest asset that any utility can have. Taste and odor control has always been the chief problem in Waterford's relations to its customers. The supply, which is of swampy origin and badly polluted with industrial wastes, including that from sulfite pulp plants, has received a large amount of re-

TABLE 1

Year	Receipts	Operating Expenses (approximate)	Mains *mi.*	Hydrants *no.*	Valves *no.*	Meters *no.*	Services *no.*	Water Pumped *mil.gal.*	Sold Through Meters *mil.gal.*
1912	$ 9,965	$10,000	10.5	101	118	742	912	No record	No record
1920	14,152	25,041	11.1	103	155	816		192	72 (85% metered)
1932	19,950	14,577	12.4	114	224	1,008		92	81 (100% metered)
1944	20,932	17,087	15.3	134	331	1,071	1,160	118	101

NOTE: Rates were increased 50 per cent between 1912 and 1920, reduced 20 per cent between 1935 and 1944. In 1912, 8 per cent of the mains were small wrought iron. They are now all of cast iron.

search and the application of the latest ideas and methods. Some have failed but others have proven of more or less benefit (3–10).

Waterford has a well-equipped shop with some machine tools and does its own repair work. It maintains all meters, pulling domestic meters once in ten years for test and overhaul. Small meters are required to operate at a rate of ¾ gpm. and measuring chambers or disks that do not come up to that standard are junked.

Comparisons

Shown in Table 1 are some major items taken from annual reports. In reviewing these figures it should be noted that over half of both system and consumption are outside of the village of Waterford. For per capita data the figure 5,500 is used, which is not over 15 per cent more than it was in 1912. Receipts include a 50 per cent increase in rates between 1912 and 1920 and a 20 per cent reduction in 1932. The present maximum rate is 25¢ per 1,000 gal., with no minimum or service charge. Table 2 is a brief statement showing the allocation of income over and above that required for operating expenses.

TABLE 2

Expended From Earnings 1923–1944 Inclusive

Repairs	$30,000	
Extensions	57,000	
To Supervisor (to apply on bonds)	43,000	$130,000
Town raised by taxation		$151,000

NOTE: To offset this tax the town received without charge water for street and sewer flushing and fire protection from an average of 125 hydrants.

The department realizes that its bookkeeping is faulty and its rates are too low. There is no depreciation account, but the works are kept in repair. Little return on capital invested is received, but most of the extensions are financed from earnings. If a hydrant rental equal to that enjoyed by some privately-owned plants were received the town might be getting rich.

Summary

1. The establishment of a board consisting of businessmen, who are free from all political influence and who have complete control, is the first and most important step toward the successful operation of any publicly-owned utility.

2. Reasonable regulations should be established, to cover the use of the service. They must be enforced impartially, without fear of changing them from time to time if conditions warrant.

3. There should be reasonable rates and they should be collected from all consumers. Schools, churches and even the town hall and public parks pay regular rates in Waterford. It is wise not to make adjustments for high bills. Because a consumer wastes a lot of water is no reason why a department should donate a part of it. Once a department has started on an adjustment program it might as well throw away its meters.

4. Competent help should be employed and paid a living wage. Trade papers and magazines should be subscribed to and the superintendent should belong to one or more of the national societies, not only for what may be derived from the formal papers given at meetings but also for the contacts made with fellow craftsmen. Some of the employees should go to nearby meetings and should have access to the trade journals, etc. They should attend state schools, if such are held in the state, and their expenses should be paid.

5. Care should be used in buying, and bills should be paid promptly. A good credit rating is as valuable to a public concern as to a private business. A local dealer should not be given license to gyp the water department because he lives in the town. Buy wholesale if necessary; he does.

6. Public relations will benefit if the water department employees will listen to all complaints and, instead of depending on the telephone, will take time to make personal calls. It is remarkable how that fighting voice that came over the telephone will prove rather mild when met face to face, and the business trip may end in a friendly chat about the boy in service or victory garden prospects. All complaints, no matter how absurd, are legitimate until proven otherwise and the man who is trying to put something over knew all about it before you did and it is not necessary to tell him. Many a time has the author called regarding a high bill where there had been "absolutely no leaks" and found a toilet with all new valve gear. Some excuse is made about taking it up with the board and it is forgotten. The bill will be paid. It does not improve the water department's standing with the public to call a man a liar even if he is one and knows it.

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Problems of the Small Town Water Works

By R. E. Dillery

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A contribution to the Journal

A FIRST-CLASS water works man in a small town needs the wisdom of a Solomon, the patience of a Job, the political tact of a Jim Farley, the tenacity of a General McArthur, the diplomatic ruthlessness of a Von Papen, the strength of a Pittsburgh steel worker and a doctor's degree in engineering.

In most cases the supervision, maintenance and operation of a small water works system are intrusted to one person, generally someone who has a regular position in some other vocation and operates the water system only as a sideline. The town council may vote to bond the community to pay as much as $100,000 for the installation of a water works system and then turn the entire operation over to almost anyone who will do the work for $40 or $50 a month, regardless of experience. Little do the people realize that the investment they have made in the water works is being placed in jeopardy by careless or inexperienced operation.

From the operator's viewpoint, his is often a thankless job. Like the old-time country doctor, the small town water works operator must be available at all hours of the day or night, during all kinds of inclement weather, to answer a call to cut off a meter because of a frozen pipeline or because Junior knocked off a connection. Not the least of his problems is the appeasement of customers who complain of high rates, faulty meter reading, taste and odor, etc.

The author has found that one of two stock answers will usually satisfy the customer who complains that the rate is too high. Either we offer to give away all the water to anyone who will come to the plant to get it or we point out that we are delivering three 3-gal. buckets of water to the house for one cent, and that even if they had a well on the back porch, they would have to pump three buckets of water and carry them into the house before they could save a penny.

We placate those persons who think that the operator can set the meter to short change them by explaining the operation of the meter, and pointing out that the meter is more likely to short change the company than the customer.

Demonstrations that gold-fish would live in a water with 2 ppm. of chlorine satisfied the fish man, and showing that 2 ppm. caused no more damage or rust on steel wool than would raw water mollified another complainant. The chlorine residual in the Guthrie, Ky., city supply is only 0.4 ppm.

Another complaint is made by the person who knows that his meter is not read. In one particular case we found that a man was using a wire from an automobile coil to tie his meter

box shut. The wire was so small it was hard to detect, but it was discovered and the customer was invited to be present when the meter was read.

Cross-connections cause a good deal of grief for most water works men. The Kentucky State Board of Health has an order than none shall exist, but it would take a Charlie Chan to prevent most cases. It is difficult for the customer to understand that his creation of one such connection endangers the whole water system. The red tape and effort entailed in the prevention of the creation of cross-connections may not seem worth while to the small water company.

Many of the more prosperous property owners have their own pressure systems. In certain months of the year when the demand is great such systems may fail to supply the demand and go dry, and in order to provide for such contingencies the owner will want to tap the city water without cutting off his own supply. Hence a valve will be installed that can be turned on and off as needed.

The water purveyors' policy must be to prevent any possibility that the valve may not be shut off, thereby permitting water from a polluted source to enter a central distributing system. Customarily the water works man will make an open outlet on the private system. However, the home owner's plumber will often reconnect in a few days. The only sure way to prevent such a practice is to deny service to any customer with an auxiliary system.

Such examples indicate the need for an operator of considerable diplomacy.

Guthrie Water Works

Guthrie, Ky., a town of 1,300 people, is situated on the Louisville and Nashville Railroad, where the line between Memphis, Tenn., and Bowling Green, Ky., crosses the line between Evansville, Ind., and Nashville, Tenn. It is situated in a bowl on top of a hill so that water drains through the main part of town and circles the town nearly three-quarters of the way. Although sewage disposal and drainage are practically nonexistent, no case of typhoid fever or any form of dysentery has ever been contracted, as far as can be learned, within the city.

Prior to 1916 water for drinking was secured from individual drilled or dug wells, most of them dug and of the shallow type—none over 40 ft. A system of 4-in. iron mains was maintained by a private concern for a limited number of customers. No measures were taken to insure a safe potable water either by filtration or sterilization. The source of supply was a large intermittent flowing spring and a shallow well located within the town limits, the source of which, as later tests revealed, was merely surface water which became turbid after a rain. A wooden tank, with 10,000-gal. capacity, provided storage space. The pressure at best could not be raised to more than 20 psi.

After the occurrence of several large fires the need for a better water system was realized, but it was not until the Kentucky State Board of Health condemned the supply that steps were taken to fill the demands of the citizens for a supply that would meet both purity standards and fire protection needs.

After a preliminary survey, it was decided in 1934 that a system be installed using deep wells as a source of supply. The Public Works Administration was to issue a grant of $89,000 and the city of Guthrie was to issue revenue bonds of $60,000 for the

installation of wells, mains and an elevated tank. These bonds were sold to the Reconstruction Finance Corporation.

Roughly, the original plan called for a supply furnished by two wells, a pump house, one 150,000-gal. elevated tank, 3 mi. of 8-, 6- and 4-in. mains, and 40 fire hydrants. All mains were to be in circuit and equipped with laterals so that there would be a minimum of dead ends.

Services and Meters

All house services were laid with copper pipe with goose-neck connections at the corporation cock. Arctic meters were installed in Mueller yokes and cast-iron meter boxes were used.

Because the regulations in the original set-up required that all meter boxes, yokes and meters be installed at the property line on city streets, most of them were in the gutter. Thus the meter reader, after every rain, had to carry a "bailer and shovel," for most of the meter boxes were full of either dirt or water. Recently the meter boxes have been moved either into the sidewalk or to the inside of the walk. A total of 79 meters were moved at a cost of about $10.00 per meter.

The meters have given excellent service. At first, a great many meters had to be changed because the hardness of the water produced corrosion and scale which caused the diaphragms to stick and the water passed through without registering. Trouble also resulted when water from hot water heater tanks backed up into meters and warped the diaphragms. Restaurants and hot water furnaces were responsible for all such cases. Check valves eliminated the trouble.

In meter yokes, another worry appeared for the superintendent. A mechanic found that he could cut a slot in one end of a piece of 1-in. pipe and with it shut off the meter in cold weather, thus keeping the pipes from freezing. He could also thus make connections in the house without calling for the water man. Several of these wrenches were made. The users thought that several turns were required to cut off the water and consequently when the valves would stick they would apply too much pressure and break off the bronze five-sided nut. Then the water department would be called in and its representative would have to dig to the main and cut the water off at the corporation cock.

After several of these "accidents," an order was issued to the effect that the cost of such a repair, including the cost of a new yoke, would be assessed against the offender, the same to be paid before service would be resumed.

Development of First Supply

Specifications for the wells called for a maximum pumpage of 200 gpm. Two wells were drilled, one 360 ft. deep and one 364 ft. deep, both with 8-in. casings. A test revealed that the volume met the specifications.

The contract for the laying of mains and the erection of the elevated tank was completed and accepted by both government and city engineers. The pumps were started after the mains were sterilized and flushed and the system placed in operation.

Nothing was said in the specifications regarding the chemical quality of the water. The contract merely called for a water acceptable to the Kentucky State Board of Health. This was unfortunate, as later events proved. The water from the wells was very hard. In addition, it was sulfur water. The accompanying table shows the

chemical properties of the well water.

Because of the extreme hardness and sulfur taste the water was very unsatisfactory—so much so that it was not used except for sanitary purposes. Soap consumption rose and corrosion reached a point where service lines in a hot back at the restaurant had to be replaced every 60 days.

After discussing the situation with the RFC engineers, it was agreed that some form of softening system should be installed. A supplemental grant was given by the government and $18,000 in revenue bonds were issued for the installation of a softening system. After tests were run it was decided that aeration and zeolite greensand were the solution to the problem.

After the softening plant was put into operation it was noted that the total hardness of the wells differed. Well No. 1 showed a hardness of 684 ppm., while well No. 2 showed 1,112-ppm. hardness.

The specifications for each softener were based on a 684-ppm. hardness and on that basis it was assumed that 10,200 gal. could be treated in 3¼ hours. The maximum rate of softening for each tank was 45 gpm. The wash rate was 170 gpm. and the rinse rate 44 gpm. The amount of salt required for the regeneration of each softener was 159 lb. However, only 6,280 gal. from well No. 2 could be treated under equivalent conditions.

The normal demand of 25,000 gpd. required about 640 lb. of salt per day, or 10 tons per month. The cost of Grade A salt, at $22 per ton, amounted to $150 per month. This, plus the fact that the wash and rinse water was 50 per cent of the treated water, made the system very uneconomical, especially with a limited number of customers. Because of the excessive cost of finished water after so much time and funds had been expended, it was decided to look for a new supply.

Louisville and Nashville R.R. Supply

The Louisville and Nashville Railroad Company has a pump station about 3 mi. from Guthrie from which it secures from a spring all the water needed for engines. While the water is good steam water, because of surface surroundings, it is badly contaminated. Also, during rainy seasons it becomes extremely turbid. The turbidity varies between 10 and 2,000 ppm.

An agreement was made between the city of Guthrie and the railroad company, whereby the railroad company agreed to sell to the city water at the rate of $0.075 per 1,000 gal. with the condition that the city would pay the cost of cutting and piping from the railroad main to its own plant.

The main of the L. & N. R.R. was tapped at the point nearest the city pump house and a 4-in. main run to the outside storage tank at the pump house.

While the chemical content of this water is not such that it can be classed as a very soft water, it is so much better than the well water that it was decided merely to filter and sterilize, using the zeolite as a filter medium. This is the system in use at present.

The table shows the chemical analysis of the two wells, the L. & N. supply and the finished water.

Filtration

As no knowledge was available regarding the use of zeolite as a pressure filter medium or the use of the softening tanks as containers for a pressure filter, a good deal of experimentation was necessary.

The brine line from the measuring

Chemical Analysis of Well and Spring Water

Analysis, *ppm.*	Zeolite Medium		Sand Filter	
	Well	Tap	Spring	Tap
Total Hardness (as $CaCO_3$)	906.0	56.0	220.0	220.0
Calcium Hardness	669.0	—	156.0	156.0
Magnesium Hardness	237.0	—	64.0	64.0
Alkalinity A (Methyl Orange)	194.0	184.0	175.0	175.0
Alkalinity B (Phenolphthalein)	0.0	0.0	0.0	0.0
Causticity (Alkalinity C)	0.0	0.0	0.0	0.0
Carbon Dioxide	22.0	6.0	7.0	5.0
Chlorides	60.0	63.0	16.0	4.0
Sulfates	514.0	0.0	25.0	3.9
Iron	0.5	0.4	0.1	0.1
Manganese	0.0	0.0	0.0	0.0
Hydrogen-Ion Concentration	7.2	7.8	7.5	7.7
Turbidity	15.0	0.4	20.0	0.4
Color	15.0	5.0	15.0	5.0

tank to the softener unit was disconnected and the pipe capped. The butterfly valves emptying the rinse water and the wash water into the sump were removed, as were the orifice plates leading from the sump, thus making possible the regulation of the wash water flow by a system of gate valves.

After many trials it was found that the rate of wash should be as near 7 gpm. per sq.ft. of filter as possible. Higher rates caused a carry-over and rates less than 6 gpm. did not furnish enough lift to carry off the accumulated wastes. The time of wash varied and depended on the turbidity of the influent. At times of low turbidity it was customary to hold as much water in the elevated storage tank as possible, and, as the source of supply, except in extreme cases (over 20 ppm. for two days at a time), water was not pumped on these days except in emergency.

This is the system of filtration that is in operation at the present time. It produces a satisfactory water as regards clearness, sediment and color.

Sterilization

Chlorine gas is used for sterilization purposes. All water is pre-chlorinated so that the filter medium is at all times sterilized. No means are available for post-chlorination and, up to the present time, there has been no need for it. The author believes, however, that some equipment should be installed so that post-chlorination could be used if necessary.

The raw water has a chlorine demand of from 0.5 to 12.0 ppm., depending on the turbidity of the water. Chlorine is applied with a Wallace & Tiernan chlorinator at the rate of 5 lb. per day. This amount allows for a residual of 0.4 ppm. through most of the system and on the extreme limits the residual never falls below 0.2 ppm.

Samples of the treated water are sent to the state laboratory every two weeks for analysis. Up to the present time all samples show the water to be potable as regards bacteria content.

pH Control

At the start of operation of the system many complaints of red water were registered, and because of the corrosion of the mains it was deemed advisable to install some means of pH control.

A pressure alkali neutralizing feed was installed at the high-lift pump house and the solution is fed at the rate of 7 ppm. into the mains directly after the water leaves the filter. The solution, which is composed of 7 lb. of flake caustic soda and 6 lb. of silicate of soda to 20 gal. of water, is mixed at the plant in the feeder. An orifice was placed in the flange connection to the main inside the plant and the differential of pressure causes the solution to be fed into the main through a needle valve.

During all the changes that were made, the rate of application was not changed and the trouble from red water has been eliminated. Recently, when the main was cut for an extension, the inside of the main was examined and it was found that a thin coating of glass-like material had completely covered the inside of the pipe.

Rates

The city of Guthrie serves water to 125 customers. The city pays the water department $800 per year for 40 fire hydrants. Under the original plan the rate was set at a minimum of $1.50 per month for 3,000 gal. furnished, with a sliding scale of 5¢ for each additional 1,000 gal. in 5,000-gal. sequence. The state tax of 3 per cent was added. After one year's operation the rate was raised to a $2.00 minimum for the first 3,000 gal. and 50¢ per 1,000 for the next 2,000 gal., with the sliding scale of 5¢ per 1,000 for each additional 5,000 gal. This latter schedule is in effect at present. The total revenue from all sources is between $350 and $400 per month.

Summary

In conclusion, the author would like to suggest to the small town operator the following precautions to be taken:

1. In locating a new source of supply be sure of the total hardness, taste and odor, as well as the quantity.
2. Place meters in locations where water does not stand.
3. Check all possible cross-connections every meter reading day.
4. Install a system for post-chlorination, as well as pre-chlorination.
5. Don't take complaints too seriously unless there are too many.

Water Consumption and Unaccounted-for Losses

By H. A. Harris Jr.

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Presented on Oct. 26, 1944, at the California Section Meeting, Los Angeles, Calif.

WATER consumption and unaccounted-for water are of prime importance to all water supply operators. Water consumption is responsible for the gross revenue of the utility, and water losses affect operating expense and consequently the net revenue. In a 100 per cent metered system it is advantageous to increase the former, and in all systems, whether they operate on a metered or a flat rate basis, to decrease the latter.

The California Water Service Company, a privately-owned water utility, operates twenty separate water supply and distribution systems serving 30 California communities. These systems are located in the Sacramento and San Joaquin Valleys, the San Francisco Bay area and southern California. The largest system is East Los Angeles, which adjoins the city of Los Angeles on the east and serves a population of 100,000. The smallest system is Lomita Park, which serves 1,750 persons. The majority of the supplies are derived from underground sources but eight systems are supplied in whole or in part by surface supplies. Some of the plants are 100 per cent metered and others are 90 per cent flat rate.

Water Consumption

Because of the extremely wide range of climatic conditions encountered the demands in these systems are quite varied. At Bakersfield, in the San Joaquin Valley, the average daily consumption amounts to 15 mil.gal. and the maximum daily consumption is 33 mil.gal. At East Los Angeles, which has 45 per cent more customers (the word "customer" as used throughout this discussion refers to an active service connection) than Bakersfield, the corresponding figures are 7.4 and 11.3 mgd. It should be noted in this comparison that East Los Angeles is a 100 per cent metered system and Bakersfield a 25 per cent metered system.

Table 1 shows the average consumption per customer in gallons per day.

The wide variation in average consumption is indicated by Bakersfield, with 1,150 gpd. per customer, and Lomita Park, with 240 gpd. On the maximum day the corresponding figures are 2,400 gal. for Bakersfield and 500 gal. for Lomita Park.

Except in the Contra Costa and South San Francisco systems, domestic and commercial customers form a very large percentage of the total and industrial use is relatively small. In the two systems named, however, industrial use is large, which accounts for the high figures per customer.

A further study of the table indicates that in general the average daily use per customer in the coastal regions is between 300 and 400 gal., whereas in the central valleys it is from 700 to 1,100 gal. The ratio of the maximum day to the average day in the coastal

TABLE 1

Average and Maximum Daily Consumption per Customer

Town	Average, *gpd.*	Maximum, *gpd.*
Bakersfield	1,150	2,400
Bear Gulch	485	925
Chico	950	1,890
Contra Costa	940	1,150
Dixon	460	875
East Los Angeles	380	575
Hanford	690	1,550
Hermosa-Redondo	350	540
Livermore	600	1,240
Lomita Park	240	500
Los Altos	900	1,510
Marysville	615	1,070
Oroville	1,120	2,500
Petaluma	310	455
San Carlos	290	590
San Mateo	320	600
South San Francisco *	1,350	1,640
Stockton	510	900
Visalia	1,020	2,010
Willows	400	885

* There are several very large industrial customers which account for these high figures.

area is from 150 to 175 per cent, whereas in the interior valleys it is 200 per cent or over.

All the larger plants have recording meters on all sources of supply and storage facilities, so that it is possible to determine rates of usage throughout all hours of the day and night. It is quite interesting to note the wide variations in this flow. A typical graph covering a 24-hour period on a peak day shows maximum hourly flow of 150 per cent of average and a minimum hourly flow of 50 per cent of average.

In one of the interior valley plants an extensive study of demands was made and it was found that approximately 24 per cent of the total daily water consumption occurred during the period from 5 to 9 P.M. If it were possible to spread the consumption during this period over a longer period, thus smoothing out the use curve, it would mean that less pumping and storage facilities would be necessary to meet the load, which would result in savings in both capital and operating expenses.

An educational campaign on the proper use of water for lawn and flower irrigation was conducted during 1943. The results showed that the maximum hourly flow was reduced from 150 to 140 per cent of the average hourly flow and that the consumption during the 5 to 9 P.M. period was reduced from 24 to 22 per cent of the total daily consumption. This represents a saving of 500,000 gal. of water during this period. To supply this quantity would have required additional well pumping capacity of 2,000 gpm. or additional storage capacity of 500,000 gal. The effectiveness of the educational program is thus very clearly demonstrated.

Unaccounted-for Water

Unaccounted-for losses can always be studied with much interest. In the statistics here cited the term "unaccounted-for water" means the difference between water produced and delivered to the system and water delivered through meters to the customers. Thus unaccounted-for water includes that lost due to slippage of meters, water used for extinguishing fires and flushing streets, water used in flushing the distribution system and leakage from mains, services and distribution reservoirs. There is no absolute standard of the percentage of water which should be accounted for. An amount less than 80 per cent should certainly be a subject for study and probably a leakage survey. If the water accounted for is 90 per cent or more there is little possibility of further improvement.

One of the systems in the central coast area showed an abnormally high amount of unaccounted-for water. The essential parts of this system were a 5-mi. transmission main, a 3-mil.gal. distribution reservoir and 70 mi. of distribution mains. It was decided to check losses in these three separately. The first test was for leakage from the reservoir. The reservoir was shut off during a four-hour period at night when the entire demand could be supplied directly from the source of supply. Leakage was determined by measuring the drop in level over a four-hour period and was found to be at the rate of 84,000 gpd. The reservoir was later drained and numerous horizontal and some vertical cracks were found. They were repaired by chiseling out a notch along the crack about 2 in. wide and ¾ in. deep, then laying mesh over the cracks and guniting a strip 2 ft. wide. The reservoir had to be kept out of service for four days to accomplish this repair work.

The leakage test was repeated about six weeks after the cracks were repaired. No measurable leakage was found in a four-hour test period. This eliminated the reservoir from further consideration.

The second step was to measure leakage in the distribution system. This was determined by shutting off all supplies to the town during a four-hour period early in the morning and determining delivery to the distribution system by measuring the drop in the level of the reservoir. The meters of all industrial customers were read during the period. After some spot checks and a study of all available literature a night usage of 2 gph. per service for all domestic and commercial customers was determined. Deducting the total usage from the delivery out of the reservoir resulted in a distribution system loss of 140,000 gpd. This amount, reduced to loss per mile of main, was 2,000 gpd. While this was quite high, it was considered reasonable for this system.

There remained then the transmission main loss, which amounted to 130,000 gpd., determined by deducting the reservoir and distribution system losses from the total known losses. This was extremely high and a survey of the entire line was made with a leak detector. Several bad leaks in this line were discovered and repaired and the losses materially reduced. Further surveys are being conducted in the hope of further reducing the losses.

Continuous records are necessary in order to compile data on consumption and unaccounted-for losses. Every water department should keep such records and study them frequently in order to plan ahead to meet growing demands.

Control and Elimination of Pest Infestations in Public Water Supplies

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A contribution to the Journal

NUMEROUS infestations of public water supplies by such pests as midge fly larvae and crustacea have been reported in water works literature. Malloch (1) describes, for example, a specimen of the species *Chironomus viridicolis,* obtained in December 1914 from the reservoir for the city water supply of Champaign, Ill.; even earlier, in 1896, Osborn obtained a larval specimen for study from the city water supply of Boone, Iowa, to which he gave his name—*Chironomus osborn.* Brown (3) and Arnold (4) recite experiences with such pests on the West Coast, Arnold reporting that *Chironomus* larvae infestations have occurred at a number of California plants. A London Metropolitan Water Board report (5) mentions tests made with mineral oil as a larvae control measure in a London reservoir and Buchmann (6) wrote of difficulties with these organisms in German bathing places, swimming pools, water supplies and activated sludge plants (7). A blood worm infestation of a clear water reservoir in Cincinnati was described by Bahlman (8). Other cities have had similar trouble: Hechmer (9) found *Chironomus* larvae in the raw water, settling basins, filters, clear water storage tanks and distribution system of the Washington Suburban Sanitary District during two summers. The larvae were found regularly ahead of filtration in the Canal Zone by Enslow (9). Filby (10) called attention to the presence of red worms in stored artesian well waters in Florida; and small red and white worms were found in the water supplies at Charlottesville, Va., and Elizabeth City, N.C. (11), and also at Champaign, Ill. (12). The author has encountered them at Peoria, Ill. (13), and in 1945 at Alexandria, Va. (14). In view of this undoubtedly incomplete record, it is not difficult to conclude with Carpenter (15) that this problem "seems to be popping up continuously." An attempt has been made to review in this paper the problem of controlling these and similar pests and to report on the use of DDT and other control measures that have proven successful and practical.

Biology of the Chironomids

The "wrigglers" and larvae most frequently giving trouble in public water supplies are the aquatic larval stages of the common, gnat-like flies known popularly as midges and scientifically as the *Chironomidae.* The Chironomids are true flies and belong to the order *Diptera, Chironomidae* being the name of the family division. They are among the commonest and most widely scattered of the two-winged insects, occurring on every

Chironomid or Blood Worm, Larva of the Midge Fly. Mag. About 4 ×.

continent and in all the faunal areas into which these continents have been divided. They are found from Greenland to the tropics and some of the 1,200 species known to entomologists are so similar that only specialists can distinguish between them. Others differ widely in appearance. The *Chironomidae* family is generally subdivided into three subgroups: (1) the *Ceratopoginae,* to which group belong the only biters or blood-sucking members of the family (the "sandflies" and "punkies"); (2) the *Tanypinae;* and (3) the commonest and best known, the *Chironominae,* to which group belong practically all of the larvae pests troublesome to water supplies.

A good portion of the life of the Chironomids is spent in water. The aquatic period involves the egg, pupal and larval stages. The adult, or imagine, stage is the only one spent out of water, except in the case of a few isolated species where the larval and pupal stages may be terrestial.

Eggs are deposited by the adult female fly principally in the stagnant water of pools, in ponds and in the water of slow moving streams. Some eggs are laid in clumps, others in strings. All are enveloped in a protective, gelatinous coating, sometimes of one thickness and sometimes of two. The eggs may be glued to stones, may float free or may float anchored by cords. They may occur as a single pear-shaped mass or in a pipe-like shelter. The gelatinous coating swells in water and serves to protect the eggs against fungus infection and also to separate the individual eggs for better aeration and exposure to sunlight (15). The eggs themselves are elongate, cigar-shaped and usually pointed on each end. The egg mass may contain from 500 to 1,100 eggs (1, 7), and the total bulk may run into 2 qt. (15). The length of the egg stage probably fluctuates with the weather. It is generally given as of approximately six days duration.

The Chironomid larvae may be described as soft skinned and wormlike. Practically all species are aquatic and move through the water in a characteristic undulating motion that resembles a quickly untangling letter S or figure 8. In a glass or jar of water they quickly seek the bottom. Length varies from a few millimeters to ½ and even 1 in. Practically all have gills—an important distinction from mosquito larvae. There is considerable diversity in structure and a striking range of color. Needham (2) states that these color differences lead to the distinction between "white" larvae and "red" larvae, or, as more commonly expressed, white worms and red or blood worms. Range of color is from a bright crimson to a transluscent pale yellowish, greenish or even bluish. All larvae are "white" when newly hatched,

the red color of those that become red appearing as the larvae develop and is due to the presence of red hemoglobin-carrying blood. In general it may be said that the red larvae are larger, have a more extensive development of blood gills and live in deeper and less well aerated water. The white organisms are, as a rule, smaller, have little development of blood gills or of hemoglobin in the blood plasma, and live in rapids and along the shore in shallower, cleaner and better aerated water. Either type of larvae may be present in the average water supply reservoir. While one or the other type will usually predominate, usually both types will be present. Because of their color, the red larvae are more conspicuous and therefore possibly more objectionable than the white ones.

Chironomid larvae under the microscope show a definite head structure that is almost awesome in appearance. The body is distinctly segmented, usually with twelve joints and segments in addition to the head. The twelfth segment is provided with a pair of prolegs, some setae and blood gills; sometimes there are also two pairs of conspicuous blood gills on the ventral surface of the eleventh segment.

Midge larvae differ from mosquito larvae in their method of obtaining oxygen, in their method of motion and in their body structure. Mosquito larvae, like the midges, have a segmented body but a large thorax section, that is, the second segment (next to the head) is noticeably enlarged, which is not true of the Chironomid larvae. The mosquito larvae move through the water with more of a swimming motion and obtain their oxygen supply through surface breathing. Placed in a glass of water live mosquito larvae will eventually come to the surface for air, midge larvae will sink to the bottom and remain there.

The larvae live either free on the bottom of the reservoir or in cases or tunnels. The tunnels are quite fragile and difficult to find in ordinary infestations. However, Brown (3) found the walls of a reservoir holding well water literally covered with thousands of such tubes, siliceous in character and each a shelter for a blood worm. In most cases the larvae will be found embedded in the debris and fine dirt of the reservoir bottom. The larvae feed on dead leaves and other vegetable refuse, on algae and on diatoms. Eggs of other aquatic animals and infusoria also serve as food.

Enemies consist of fish, both large and small, dragonfly nymphs, caddis worms, beetle and other predaceous larvae. Various investigators have determined that the Chironomid larvae are an important source of fish food, as many as 2,350 larvae having been found in the stomach of a Minnesota red horse (15). Needham (2) found Chironomid larvae the predominating organism in the stomachs of 25 brook trout caught and examined in Bone Pond, N.Y.

No reliable data appear to be available concerning the length of time required for the larval stage to be completed. The time varies with temperature, food supply available and other factors. An entire cycle from egg to adult has been variously reported as taking 30 days, five weeks and two weeks. Buchmann (7) found larvae developing in the laboratory in six or seven days in water at 22°C. with abundant food supply present.

The adult or fly stage is preceded by a short pupal period. This period is often extremely short and few pupae are ordinarily seen in a water supply

reservoir. The adults, on emergence, gather into and fly in swarms which may be quite large. Their flight has been described as a dancing or darting motion. The larger species of midges resemble mosquitoes but differ from them in their inability to bite, the absence of scale-like fringe on the wings and the different wing venation. The food supply of the adult is unknown. Some entomologists have thought that these flies cannot feed and therefore that the only purpose of the adult is that of reproduction. It is believed that the adult fly lives from two to nine and one-half days.

Control of Infestations

Mechanical Means

Measures for the prevention and elimination of larval infestations may be divided into mechanical, biological and chemical procedures.

Covering reservoirs and screening all vents and openings in the cover with a small mesh screen will prevent the midge fly from gaining access to the water in storage to lay her eggs. This method of preventing larval difficulties has been found to be the only reliable control measure in the West (3, 4), and similar steps were taken at Champaign, Ill.

In certain cases, however, covering the supply reservoir is not practical. This is true in many impounded but unfiltered supplies and also in existing distribution clear water storage reservoirs of large area. Under such circumstances other means of control and elimination must be provided.

Excelsior filters, while not tried specifically for keeping Chironomid larvae out of the distribution system, have been used in several instances for preventing cyclops and daphnia from gaining access to the mains. Such filters can be quickly and readily built and placing them in position is usually no particular problem. During the thirties a combination sponge and excelsior filter was placed over the outlet pipe in a 15-mil.gal. distribution reservoir in western Pennsylvania. This filter was roughly 6 ft. × 8 ft. × 5 ft. deep and was built to fit over an upturned 16-in. ell. The filter consisted of a wooden frame covered with chicken mesh wire and fairly loosely filled with sponges and excelsior. When lowered into place from a boat through approximately 20 ft. of water it proved effective and immediately stopped crustacea from appearing in water drawn from household taps on the system. This filter remained in place for over a year, long after it was required, without any ill effects.

During the summer of 1945 similar filters were successfully employed on two supplies—another in western Pennsylvania and one in Rhode Island. The offending organisms were in both cases crustacea. In Rhode Island the excelsior filter was used in a steel basin 20 ft. high and was lowered into place from the top. The filter prevented organisms from entering the mains, and, by drawing water from the bottom of the tank, the crustacea, which tend to stay near the bottom, were finally eliminated.

In western Pennsylvania, the filter employed was roughly 6 ft. × 3 ft. × 3½ ft. The 6 ft. × 3½-ft. side was braced against the 16-in. suction main feeding a 1,000-gpm. booster pump approximately 1,200 ft. away. This filter effectively stopped the crustacea from entering the system. At the time of this writing it has been in place for approximately four months and has caused no trouble nor has there been any noticeable decrease in the suction

pressure of the pump, as would be the case were the filter offering any obstruction to the flow of water. From these experiences, it would appear that excelsior filters will provide, in many cases, a rapid, ready means of temporarily overcoming a larval or crustacean infestation.

Biological Methods

What may be termed, for want of a better name, "biological methods of control" depend for their success on the interruption, in some manner, of the biological development of the insect. To this type of control may be ascribed such methods as:

1. Keeping down vegetation in the vicinity of the reservoir. Midges seem to prefer higher weeds in which to rest during the daytime. Keeping such vegetation mowed down removes a likely harboring place and may possibly destroy a source of food for the adults. At Peoria, Ill., such a procedure has apparently aided in discouraging midge flies from remaining in the vicinity of a reservoir.

2. Removing one source of food supply of the larvae by keeping down algae growths. This is particularly true on sloping and shallow reservoir walls. Rolling large crystals of copper sulfate down such slopes has been found more effective for this purpose than applying the chemical in the usual manner.

3. Stocking the reservoir with fish.

4. Emptying the reservoir and keeping it out of service six or seven days to eliminate one generation of flies by destroying the eggs. This is seldom possible.

Chemical Methods

While Carpenter (15) states that copper sulfate will eliminate midge larvae from reservoir water, this is contrary to the author's experience and the reports of others. Arnold (4) says that Chironomid larvae will withstand chlorine concentrations as high as 50 ppm., with a contact period of 24 hours; also that 50 ppm. of copper sulfate is ineffective. These figures are corroborated by Brown (3), who also notes that the eggs of the organism he reported on were unaffected by normal pre-chlorination dosages of chlorine. Buchmann (6) reported that 50 ppm. of copper sulfate did not affect the larvae and that such a dose did not prevent pupae from emerging. He states, however, that chlorine will kill the larvae; he found that 25.8 ppm. chlorine constitutes a lethal dose within one and one-half hours, 12.99 ppm. in three hours and ten minutes, and that 80 per cent kill is obtained after 24 hours' contact with water dosed with 6.50 ppm. Copper sulfate added with the chlorine hastens the killing time. In Alexandria, Va., a chloramine residual of approximately 1.0 ppm. did not prevent eggs from hatching nor did this residual have any effect upon the activity of a white larva found there in August 1945. Four pounds of copper sulfate per million gallons applied to this same reservoir water had no noticeable effect upon the larvae. In laboratory tests 10 ppm. of chlorine did not kill the larvae nor did 10 ppm. of copper sulfate. At Peoria, Ill., in 1940, Chironomid larvae retained their activity for a period of over an hour in a rough qualitative test in which large excesses of hydrated lime, copper sulfate and HTH were added simultaneously to water in which larvae were present. Buchmann found that rendering the water acid (pH 2.0–4.0) or highly alkaline (pH 8.5–10.0) had a killing effect. He also

found that 3 ppm. of an insect powder containing pyrethrum was effective, as was also rotenone in small amounts. From these reports it appears that ordinary chemical treatments used in water works operation are not effective in the control of Chironomid larvae.

A mineral oil was used, at least experimentally, on one of London's water supply reservoirs to control these larvae (5). Since 1940, a mineral oil known as Acme White Oil (viscosity 80–85 at 100°F.) has been used each summer for a similar purpose with apparent success at Peoria, Ill. The oil is used on a 15-mil.gal. capacity open distribution reservoir of the Peoria Water Works Company. This treatment was begun during a larvae infestation for the purpose of keeping air from any eggs that might be laid by adult midge flies, to prevent pupae from flying away as they emerged, and to imprison flies as they alighted on the reservoir surface to lay their eggs. Application is begun in late March and early April and is applied as appears desirable from observations of the presence of midges about the reservoir. Beginning in about June, the oil is applied weekly until the brick walls have absorbed enough to help keep an oil film on the reservoir surface, after which application is made as often as is necessary. Oleic acid is mixed with the oil to obtain better dispersion and greater spreading. Two gallons of oil are applied each time. In 1943 and 1944 only a few isolated larvae were found in the reservoir and none found their way into the distribution system. In these years midges were present over and around the reservoir. In 1945 few midges and no larvae were seen. This oil treatment, together with intelligent supervision, good algae control and keeping vegetation cut about the reservoir, seems to have proven successful in preventing a second infestation at this plant.

The Use of DDT at Alexandria, Va.

In late August 1945, midge fly larvae were discovered in the distribution system and in the two open clear water storage reservoirs (capacity 16.5 mil. gal.) of the Alexandria Water Company, Alexandria, Va. Relatively few specimens of the organisms could be found in the system and, while only a few consumers complained, considerable work was done to prevent these pests from multiplying and developing into an "epidemic." The larvae were small—4 to 5 mm. in length—and colorless to faint greenish in color. They were identified as *Chironomidae* larvae by entomologists of the U.S. Department of Agriculture. The larvae developed in water containing chloramine residuals of from 0.60 to 1.00 ppm., with an average retention period in the reservoirs of about three days. When obtained from distribution tap water, the larvae were always quite active, although, because of their small size and color, not very conspicuous. In the few locations where it was possible to obtain specimens, the larvae were in such concentrations that from one to six organisms would be obtained in 6 in. of water in a bathtub. The larger number would be found in the first water drawn in the morning, similar drawings of water later in the day would contain but one organism, or several tubfuls might be drawn without finding any. Larvae were found, so far as is known, in only six services out of approximately 11,000.

Laboratory tests confirmed the conclusions of other investigators that these larvae are resistant to chlorine and copper sulfate, although no dos-

ages as high as 50 ppm. were tried. Copper sulfate applied to the reservoir water (containing from 0.60 to 1.00 chloramine residual), at the rate of 4 lb. per mil.gal., had no effect upon the organisms.

Members of the Alexandria City Health Department suggested that DDT [2,2-bis (p-chlorophenyl) 1,1,1,-trichloroethane or dichloro diphenyl trichloroethane] be used to eliminate the larvae. Based on various experiments of the U.S. Department of Agriculture and the U.S. Public Health Service, a dose of 0.01 ppm. was recommended. Various authorities were consulted regarding the effect of such a dosage. All agreed that 0.01 ppm. DDT in drinking water would be harmless to humans. The single application of this chemical in this concentration was approved by Richard Messer, State Sanitary Engineer of Virginia.

On August 31, 0.01 ppm. of DDT was applied to the water in the two reservoirs. This dosage figure, in parts per million, refers to the amount of DDT only, that is, for a 0.01-ppm. dose, sufficient 25 per cent DDT solution was used to give 0.083 lb. of 100 per cent DDT powder for each million gallons of water treated.* A 25 per cent solution of DDT in xylene and triton X (an emulsifying agent) was diluted in water to an approximate 1 per cent emulsion and this sprayed onto the water surface with a Civilian Defense type of stirrup pump. The boat employed was driven by an outboard motor and the wake of the boat used for mixing. The DDT emulsion dispersed rapidly, leaving no sign of its presence a few minutes after application.

Laboratory tests had indicated a 0.01-ppm. dose would affect kill in approximately eight hours, that a 0.005-ppm. dose of DDT was lethal in something slightly less than sixteen hours and that a 0.02-ppm. concentration was effective in from four to five hours. In passing it may be mentioned that none of these concentrations affected damselfly nymphs at any stage of their growth. These nymphs were present in the reservoirs also, and were experimented with out of curiosity. Killing results were somewhat slower in the reservoir than the laboratory tests had indicated might be expected. However, three days after the application of DDT the larvae disappeared quite suddenly and have so far not reappeared (October 1945). A brief chronological record of this occurrence is shown in the accompanying table.

Larvicidal Properties of DDT

Because of the possibilities of DDT in the control of larval infestations in reservoirs, a partial review of the larvicidal properties of this chemical may be of interest. It is somewhat difficult to correlate the results at Alexandria with other work because of the difference in methods of stating the dosages used. Knowles and Fisk (16) report complete control of anopheline mosquito larvae in flooding water to rice plots dosed with 1 ppm. DDT, and complete control of culicine larvae at

* If any water department is considering the use of DDT, the employee who is handling the material should be advised that in concentrated form it may produce severe skin disturbances. Before actually using preparations containing DDT, write for a copy of the mimeographed bulletin, "Labeling Insecticides Containing DDT" (revised Sept. 1, 1945), to the U.S. Department of Agriculture, Production and Marketing Administration, Washington 25, D.C.

Larvae in Tap Water Following Application of 0.01 ppm. DDT to Reservoir Water

Date 1945	Sampling Point		
	No. 1	*No. 2*	*No. 3*
Aug. 23	(First complaint of larvae received)		
Aug. 24	($CuSO_4$ applied to reservoir, at 4 lb. per mil.gal. rate)		
Aug. 31	(0.01 ppm. DDT applied to reservoir water between 9 and 12 A.M.)		
Sept. 1	Two dead larvae found in afternoon	8 A.M.—6 larvae in tub 2 larvae in second tub 7 P.M.—3 larvae in tub (1 alive, 2 dead) 11 P.M.—2 dead larvae found in 2 tubs of water (6 in.)	At this location one or more larvae could be found at almost every drawing of a dishpanful of water.
Sept. 2	No larvae found after afternoon of Sept. 1	11 A.M.—6 in first tub drawn 1 in second tub drawn 1 in third tub drawn 5 P.M.—1 in first tub 0 in second tub 11 P.M.—0 in 2 tubs	10 A.M.—6 found all alive
Sept. 3	—	9 A.M.—3 in first tub (alive) 0 in second tub 1 in third tub Afternoon—0 Evening—0	Morning—1 dead larva in 30 panfuls of water
Sept. 4	—	9:30 A.M.—0	0
Sept. 5	—	0	0

a dose of 0.2 ppm. A water-miscible DDT larvicide was used in these experiments. Metcalf and others (17) found that DDT dusts applied at rates of 0.1 lb. per acre killed mosquito larvae but gave no indication of injury to aquatic organisms other than mosquito larvae; however, 5 per cent solutions of DDT in kerosene applied at rates of 0.1 to 0.25 lb. per acre were quite destructive to populations of aquatic insects living in close contact with the water surface, particularly *Hemiptera* and *Coleoptera*. When DDT was applied in a 20 per cent solution in Velsicol (a solvent adapted to distribution by the exhaust of airplane engines), 0.12 lb. per acre gave no significant reduction of mayfly nymphs, midge larvae, beetle larvae and water fleas (*Cladocera*). The dose used at Alexandria to eliminate midge larvae was at a rate of approximately 0.40 lb. per acre; this dose had

no effect upon damselfly nymphs, as mentioned, and showed no effect upon algae or surface water bugs. Simmons (18) reports DDT applied in emulsion form (as at Alexandria) in doses of 0.1 lb. DDT per acre, which was equivalent to 1 part in from 14 to 20,000,000 parts of water, gave excellent mosquito larvae control but had no effect upon most of the plankton organisms or on the larger animal forms such as Daphnia. He reports that the following types of fish have been killed at doses of 1 ppm.: pike, warmouth bass, beam, catfish and gambusia. DDT is quite insoluble in water, although soluble to the extent of at least 0.0015 ppm., according to Carollo (19), who also cites the fact that the kill (70–100 per cent) of *Aedes aegypti* mosquito larvae is sufficiently certain at DDT concentrations of from 0.001 to 0.0015 ppm., and that these organisms may be used as assay animals for testing water containing less than this amount of DDT.

Summary

The experience with DDT at Alexandria appears to fit in with these reported results fairly well and indicates that the small dose used there gave results as would be expected. The author, however, has no desire to recommend DDT as a remedy for all larvae infestations.

Larval infestations of reservoirs can be expected to continue to give trouble to water works operators. Excelsior filters, maintenance of a thin film of mineral oil on the water surface, algae control and stocking with fish may be considered as control measures. DDT used in the small dosage of 0.01 ppm. gave excellent results at Alexandria, but it should probably be considered only in unusual cases and should not be used without full approval of the proper supervisory public health authorities.

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Predaceous Diving Beetles in Winnipeg's Water Supply

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Presented on Sept. 14, 1945, at the Minnesota Section Meeting, Fargo, N.D.

THE city of Winnipeg obtains its water supply from Shoal Lake, an arm of the Lake of the Woods, which is about 100 mi. east of the city. As the name of the lake indicates, it is shallow and the shores and bed are composed of granite. The drainage area is not suitable for agriculture.

The water is ordinarily of excellent quality for both domestic and manufacturing purposes. It is relatively soft—about 90 ppm. $CaCO_3$ total hardness, all of which is temporary hardness. The turbidity varies from 3 to 6 ppm. Maximum turbidity usually occurs in the summer season, due to the presence of plankton and decaying vegetable matter. The color of the natural water varies from 3 to 30 ppm., with an average of 10 ppm. The bacterial counts are also low—about fifteen—and gas is found only rarely.

The water flows to Winnipeg through a gravity pipeline and is stored in a reservoir system consisting of a 21.6-mil.gal. closed reservoir and two 24-mil.gal. reservoirs. After the water leaves the aqueduct it flows first into the south half of the 21.6-mil.gal. closed reservoir and then through connection pipes into the north half of the 21.6-mil.gal. reservoir. From there it passes into the west 24-mil.gal. open reservoir and then through connecting pipes into the east 24-mil.gal. open reservoir, thence to the high-lift pumping station and into the distribution system. The only treatment applied is year-round chlorination, supplemented by high-rate chlorination, copper sulfate and activated carbon during the month or two that tastes and odors persist.

Predaceous Diving Beetles

In October 1944 large predaceous diving beetles were found in a fish trap on the water service supplying a Winnipeg brewery. The water main on the street was flushed through the hydrants, but the trouble persisted and on November 4 the brewery reported poor water pressure. On examination of the fish trap it was found to be blocked and sufficient beetles to fill a 5-lb. pail were taken from this service.

An inspection was made of the trap daily for the next few days and from ten to 25 beetles were found each day, some as much as 3 in. long.

Beetles were also discovered on other water services in the city.

In the meantime the Zoology Department of the University of Manitoba had been consulted and its report indicated that the beetles were predominantly of the *Dytiscus* species, commonly known as "predaceous diving beetles." There were also some of the *Cybister* species.

Predaceous diving beetles lay their eggs in vegetation and the larvae which emerge are aquatic, breathing by means of gills. Pupation usually takes place in mud along the shore close to the water. The adults are also aquatic, but are air breathers and carry small air bubbles with them when they submerge. They can remain under the water for a moderate time, but must return to the surface periodically to replenish their supply.

Steps Taken to Overcome the Trouble

Having gained some knowledge of the life cycle of these creatures measures were then taken to eliminate them. As stated previously, the water is not screened or filtered and chemical treatment only is applied. It was decided, on Nov. 7, 1944, to drain and clean out the open reservoirs, as they were believed to be the source of the infestation. After draining it was observed that some large and literally thousands of small beetles, from ½ to 1 in. in length, were left in the shallow pools formed in the concrete bottom of the reservoirs which have only a slight grade to the drains.

The reservoirs were hosed down and swept with brooms until they were thoroughly clean. The closed reservoirs were then drained but no beetles were found in them.

After the reservoirs had been cleaned, no further trouble was experienced in the distribution system during the winter.

Observations and Experimental Work

Because it was likely that this trouble would recur in the future it was decided to use chemicals in an attempt to control the beetles. Typical beetles were placed in the following solutions: (1) chlorine and hypochlorite (up to 100 ppm.); (2) copper sulfate (up to 100 ppm.); and (3) potassium permanganate (up to 100 ppm.).

Results of the experiments showed that:

1. A ten-hour contact period failed to kill the beetles.

2. Beetles kept under water and not allowed to reach the air were dead after 24 hours.

3. Beetles survived in water under ice for 48 hours but died upon being frozen solid.

On Mar. 25, 1945, the chief pumping station operator noticed beetles in a drainage ditch in the city and on April 28 he counted 60 small and five large beetles near the open reservoir.

On April 30, two days later, beetles were again reported in the distribution system.

On May 2, a reconnaissance was made in the vicinity of the reservoirs and beetles were found in water lying in the fields nearby.

On May 3, the chief operating engineer at the pumping station caught a small beetle about ¾ in. long in the reservoir. When it was placed on the concrete slope of the reservoir he noticed that in about fifteen seconds its wings were dry and it flew 10 ft. and back into the water.

Another beetle, about ½ in. long, was taken from the reservoir and placed on the concrete at the top of the slope. In less than one minute it began to fly, rising to a height of approximately 20 ft., and was lost sight of after it had flown about 100 ft.

Beetles were found in and around the reservoirs from May 3 until June 17, when the reservoirs were again cleaned out. In the cleaning only 10

per cent of the quantity found the previous November were removed.

Beetles have appeared in the reservoirs until the present time but in quantities not large enough to prove a real nuisance.

The Zoology Department was again consulted. They concluded that the elapsed time between the cleaning of the reservoirs last November and this June was insufficient for the beetles' life cycle in the reservoir and that therefore they must be coming in from Shoal Lake.

In June, a screen cage was placed in the aqueduct discharge line but no beetles were found in the catch.

Conclusions

The following tentative conclusions have been arrived at:

1. Beetles fly in from the surrounding countryside.

2. They do not come in from Shoal Lake in any great numbers.

3. Cleaning out the reservoirs is only a temporary solution.

4. In the absence of filtration a self-cleansing screen would eliminate the trouble.

5. Ordinary chemical means are not effective in eliminating beetles.

6. Inasmuch as this trouble has arisen only last year and this year, and in view of the fact that this supply has been operating for 25 years, the trouble would appear to be cyclic, and expensive changes should not be undertaken unless the trouble persists year after year.

Very little information on the subject was available in the literature and any conclusions or results of brief experimentation reported here should be subject to further study for confirmation or otherwise.

Fundamental Technics for Running Jar Tests

By J. B. Nickel

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Presented on Sept. 14, 1945, at the Joint Meeting of the Western Pennsylvania Section and the Pennsylvania Water Works Operators Assn., Pittsburgh, Pa.

SOME of the larger water laboratories have made rather extensive studies to determine just how much can be accomplished by, and how much reliance can be placed in, jar tests. Such studies have shown that the time of mixing, the speed of mixing, the shape of the jar, the method of introducing chemicals, the solutions used, the temperature and even the location in which the tests are performed have a very decided effect on the final results. Naturally, running jar tests as a part of a research project presents a far different problem from the one arising when such tests are run in the routine operation of a plant, and the average water works operator need not observe all the variables that may occur in jar tests. On the other hand, there are certain fundamental practices which one must follow if the results obtained are to have any meaning.

It is the author's purpose to discuss the jar test from the standpoint of routine operation, such as in the determination of operating dosages. Because the author is associated with manufacturers of ferric sulfate, particular reference to its use as a coagulant is made throughout. It should be borne in mind, however, that the same principles may apply when other coagulants are used.

Preparation of Solution

The first step in the jar test procedure is the preparation of stock solutions. Because very small samples will be taken as a gage against which to measure plant operation, these solutions must be weak in order to avoid a large percentage of error in almost every instance. In making such weak solutions, the chemicals should be weighed on a laboratory balance and distilled water should be used.

Another point to remember in preparing the stock solution is that a representative sample of the coagulant should be used. To obtain such, a fairly large sample of several pounds should be quartered. A portion of a quarter is then taken and ground into a mortar and this quartered again. The sample taken from these quarters may then be retained for making solutions. This procedure should be followed regardless of what coagulant is used.

After weighing the portion for the stock solution of ferric sulfate, a small amount of water is added. The solution is then heated to approximately 160° for five minutes and stirred occasionally. The complete solution is characterized by a dark, reddish-brown color. If the material is allowed to boil while being put into solution, a

certain amount of hydrolysis or conversion to ferric hydroxide will occur and the results will thus be invalid. The solution may be made without heat, but such a procedure is not recommended, since too much time is consumed and, quite frequently, because of this, the operator will not get the material into complete solution for the first test.

After the solution is complete, the sample is diluted to the desired strength.

Weak solutions of alum may be made and stored in the laboratory very satisfactorily. Ferric sulfate, however, is somewhat more active chemically than aluminum sulfate and weak solutions of this material tend to hydrolyze rather rapidly. For this reason it is recommended that no stock solution of less than 2 per cent strength be maintained for more than one day. It has been found that the old solution quite frequently will not give results at all comparable to the new.

Solutions with a strength of from 2 to 10 per cent may hydrolyze slowly under proper conditions. It is therefore recommended that a strong stock solution be prepared from which daily dilutions may be made for use in routine plant control. For example, 17.1 g. of ferric sulfate dissolved in 100 ml. of water will produce a 17.1 per cent solution which is sufficiently strong to avoid any hydrolysis. Ten milliliters of this solution diluted to 100 ml. is then used for routine tests. Thus, 1 ml. of this final prepared daily stock solution in 1 l. of raw water will give a dosage of 17.1 ppm. It is the author's recommendation that, even with a solution as strong as the original, a new solution be made up at least once a month. This procedure is also recommended for lime, alum or any of the other chemicals which may be used.

Location of Test

After the stock solution has been prepared, the location of running the jar tests should be selected. This operation should never take place in strong sunshine, as it is not possible to obtain an accurate picture of the settling characteristics of the floc because of the strong convection currents which are set up. For the same reasons radiators and other sources of heat should be avoided. Of course the best method is to run the jar test and let the jars settle in a water bath, but this is not feasible in most plants.

Selection of Jars

In the selection of jars for these tests, the important criterion is uniformity, not roundness or squareness. Fewer dead areas and more uniform results are obtained, however, if round containers are used. Jars should have a capacity of at least 1 l. The author's experience with jar tests leads him to believe that uniform results cannot be expected with samples of less than 1 l. Samples of 2 l. give excellent results but are not really necessary or essential.

The rate of the paddle, the design of the blade and the time of mixing are all variables which must be more or less correlated to the particular plant design and will be discussed in detail later. Generally speaking, a good jar test should receive a fast mix for about three minutes and a slow mix of about twenty minutes. The author has found in some instances that to duplicate plant results it is necessary to use four different speeds of mix in the test. The time of the total mix varies from ten to 45 minutes. It is suggested that at

various times during the year an attempt be made to calibrate the jar tests to the plant operation. Thus, if 17 ppm. is used in the plant and producing a specific type of results, only 17 ppm. should be used in the jar test but the speed of mixing, the time of mixing, etc., should be varied until one of the jars shows results similar to those being obtained in the plant. Proper mixing in the jar tests will indicate a definite relation to the dosage that must be used in the plant to obtain satisfactory operation.

In one particular plant it was impossible to get jar tests absolutely equal to plant results. However, it was found that, under certain very simple mixing conditions, by adding 25 per cent to the dosage shown in the jar test, results similar to those in the plant could be obtained. It should be stressed that each plant will have its individual problems and it is impossible to say just what the proper mixing times and speeds should be in each particular case. Usually, for a 2- or 3-in. blade, 100 rpm. is satisfactory for a fast mix and 25 to 40 rpm. provides a satisfactory slow mix.

Addition of Chemicals

The addition of the various chemicals is a very important part of the jar test. Any one chemical should be added to all the jars simultaneously, if possible. This frequently cannot be done but every attempt should be made to complete this addition as rapidly as possible, for the reason that, in many instances, the variation in the time of the fast mix, which is caused by the slow addition of chemicals, will be sufficient to influence materially the final results.

The jars should be in violent agitation when the chemicals are added. This is especially true of the coagulant. The coagulant starts to work immediately upon introduction into the water and, unless it is dispersed throughout the body of water very rapidly, the chemical reaction will occur in a small portion of the jar and the remainder will not be properly treated. This is true in both plant operation and jar tests.

One plant, after extensive work on jar tests, found that it could obtain uniform results only if the following procedure were followed:

1. The jars are dosed with all chemicals used prior to the addition of the coagulant and the solution is mixed just enough to insure uniform distribution of the chemicals.
2. The jars are withdrawn from the mixer and dry jars are inserted in their place.
3. The coagulant is added to the dry jars.
4. The mixer is started at fast speed.
5. The contents of the original jars are dumped rapidly into the jars on the mixer and mixing time starts at that point. (This provides for the simultaneous addition of chemicals during a very violent initial mix.)

The chemicals must be added to the jars in the same order as they are added in the plant. High-rate chlorination frequently affects coagulation and, if accurate results are desired, the jars should receive high-rate chlorination at the same rate at which it is being applied at the plant, and the same retention time should be allowed between the addition of the chlorine and the addition of the next chemical. If lime is being used for pH control, whether before or after the coagulant, it has a very surprising effect on the coagulation. For color removal, the coagulant

should be added well ahead of the lime in order to avoid color fixation. On the other hand, for a taste and odor removal by coagulation, every effort should be made to maintain the raw water pH. In this instance, the lime should be used ahead of the coagulant, but the coagulant should be added as quickly thereafter as possible. Simultaneous addition is satisfactory if a very violent rapid mix is being employed in the plant. For straight coagulation, however, any pH adjustment should be made well ahead of the coagulant addition in order to secure the most economical results.

Generally speaking, jar tests should cover dosages extending far below the dosage anticipated to well above it, observing rather wide jumps between the individual jars. This will enable the immediate determination of the general range in which the dosages should be made. The jar test can then be repeated using small increments and the most economical dosage determined. A great many variables must be considered in selecting this dosage. For example, from two to fifteen minutes can be allowed for settling of the turbidity, the exact time depending on individual plant characteristics, the results desired, etc.

The author believes that the water should be as clear as possible down to about 2-ppm. turbidity and the filter allowed to act only as a safety factor. However, many operators do not share this opinion. Generally, the dosage selected should be the one that, at the most economical costs, gives a water meeting the requirements after a designated settling time. The proper jar should be selected by turbidity determination rather than by guess. Floc color, size, etc., will not affect a turbidity test but may be very deceiving to the naked eye.

Synthetic Ion-Exchange Resins

By W. C. Bauman

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A contribution to the Journal

WHAT is a synthetic ion exchange resin? What are the properties of such a resin? Are these properties unique for one particular type of chemical structure? To what useful purposes may these properties be put? These are some of the questions which will be discussed here, in the hope that broader uses for these materials may be found as they become more familiar.

The phenomenon of ion exchange, in particular of base exchange, is certainly neither new nor complex. Ion-exchange reactions are proceeding naturally all around us and this exchange function in the fertility of soils led Thompson and Way to the first study of the base-exchange reactions in 1845. This study soon led to the important discovery by Eichhorn that the absorption of ions from ground water by clays was a reversible reaction; i.e., the clay could be loaded at will with any cation (Ca, Mg, Na, K, NH_4, etc.) and then this cation could be replaced with any other cation. This discovery led reasonably to the use of natural siliceous materials, such as greensand and bentonite, in the softening of water supplies.

Subsequent development has been in improvements of the exchange properties of greensand. Chemical and physical modification of greensand, synthesis of sodium aluminum silicates of controlled composition, the identification of exchange properties in peat, lignite and soft coal, the improvement of these materials by sulfonation and the synthesis of organic sulfonated resins have been important steps in this improvement of the raw material for base-exchange reactions. The progress in improving the exchange capacity of these materials is shown in Fig. 1. The ultimate in exchange capacity is unknown at present. Doubtless it has not yet been reached and this factor remains a distinct challenge to research in this field.

Progress in this application of a wide variety of materials to the base-exchange reaction has clarified the nature of the ion-exchange reaction and the required structure for a good ion-exchange material. Figure 2 shows approximate structures for inorganic and organic exchange substances. It is noted that the two fundamental features of these structures are:

(1) A sturdy cross-linked network of atomic chains to insure the insolubility of the material in water or other ionizing solvent.

(2) A multiplicity of ion-active groups, such as —Si—O—Na, —COONa, —SO_3Na, etc., attached to this basic structure.

The physical properties of the exchange material, e.g., the insolubility or lack of color throw, the stability to heat, acid, alkali and oxidizing agents,

the mechanical strength of the particles and the diffusion rate of ions through the particles, are determined by the composition and structure of the basic network. The chemical and ion-exchange properties of the material, e.g., the total exchange capacity, the selectivity for one ion over another, the change in capacity with varying pH, etc., are determined by the density and type of the ion-active groups.

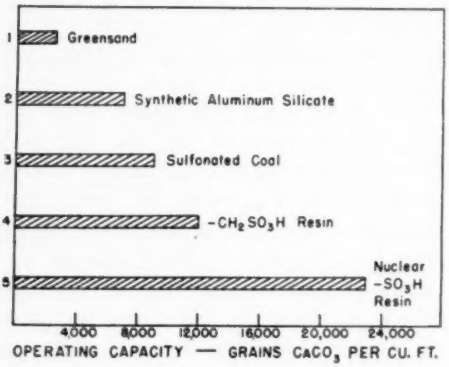
1 Greensand
2 Synthetic Aluminum Silicate
3 Sulfonated Coal
4 -CH2SO3H Resin
5 Nuclear -SO3H Resin
4,000 8,000 12,000 16,000 20,000 24,000
OPERATING CAPACITY — GRAINS CaCO3 PER CU. FT.

FIG. 1. Exchange Capacity of Cation Exchangers

The activity and development in the field of exchanging cations from solution with a solid exchange material created interest in the development of other solids capable of exchanging anions. Such anionic exchange is shown by some inorganic hydroxides, such as ferric hydroxide and hydroxy apatite. For example, teeth and bones consist of calcium hydroxy phosphates on which the hydroxide group may be replaced by chloride, carbonate, fluoride, etc., and the presence or absence of fluoride in the teeth appears to have a pronounced effect on tooth decay. Synthesis of organic resins capable of anionic exchange was first accomplished by Adams and Holmes in 1935 in England, using organic amines as raw material.

Figure 3 shows the structure of such anion-exchange materials. It will be noted that the structural requirements are the same as for cation-exchange materials, but the ion-active groups are amines. All commercial anion exchangers are amines, but vary somewhat in the type and basicity of the amine group.

Ion Exchangers in Water Treatment

With this background on the general nature of ion-exchange substances let us investigate more closely the properties of the synthetic ion-exchange resins and their application to the treatment of fresh water supplies.

There are three main fields of application of ion-exchange resins to water treatment:

(1) Water softening.

(2) De-alkalizing water, chiefly for boiler feed.

(3) Demineralization of water.

The major use of cation exchangers is in the field of water softening. In this field all types of cation exchange materials are usable and competitive. A comparison in exchange capacity is

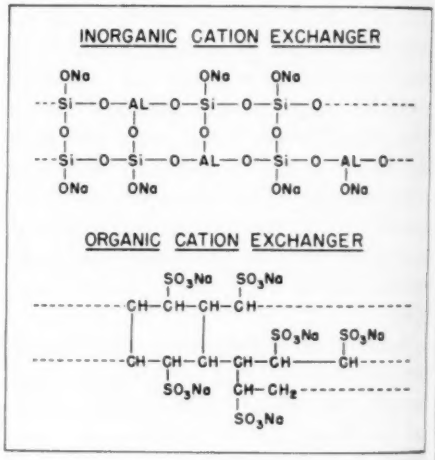

FIG. 2. Chemical Structure of Cation Exchangers

shown in Fig. 1 and more detailed information on this point is shown in Fig. 4.

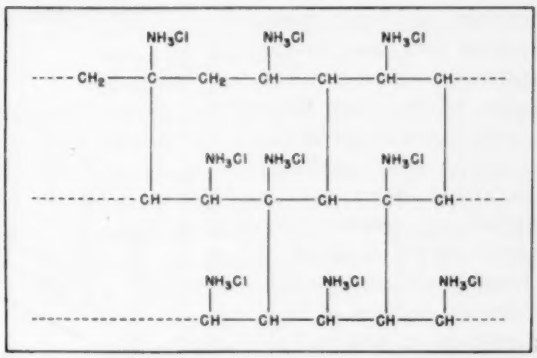

FIG. 3. Chemical Structures of Anion Exchanger

A Synthetic Resin Exchange

An improved nuclear sulfonic acid resin has been developed having 30,000 grains $CaCO_3$ per cu.ft. total exchange capacity, of which over 90 per cent is available at high salt values. The resin has a much higher diffusion rate of ions through its lattice than do the silicates, so that the exchange is a true mass phenomenon occurring right back to the center of each particle. The rate at which a sample of this resin comes to equilibrium with its ionic surroundings is shown in Fig. 5. In one minute the reaction is 92 per cent complete, and in two minutes equilibrium has been established. This speed of exchange is of major importance. Wash water requirements are low (1.0–1.5 per cent on a 171-ppm. hardness water), salt efficiencies are high (50 per cent efficiency at 20,000 grain per cu.ft. operating capacity), hardness break-through is very rapid at the completion of the run, and units may be operated at flow rates as high as 10–15 gal. per sq.ft. per minute with leakage of less than 1-ppm. hardness.

The physical and chemical stability of this nuclear sulfonic acid resin is of interest. One of the greatest difficulties in exchange resin synthesis has been to eliminate color throw.* Only slight color throw is obtained with this resin on the first cycle of operation and none at all thereafter in either the acid or sodium cycle. At pH values below 9.5 the resin is stable even to boiling water. Alternate and rapid immersion in saturated salt and then fresh water has no effect on the resin, so that any concentration of salt brine may be used for regeneration. Only two methods of breaking down the resin have been found: (1) boiling in strong acid or alkali, in which case a slow loss in capacity is obtained—and a gradual softening of the particles in the boiling alkali; and (2) treatment with strong oxidizing agents, such as Cl_2, Br_2, HNO_3, and H_2CrO_4. Field tests in both acid and salt cycles have been run for a period of three years with complete stability of the resin. Laboratory tests on the sodium cycle were operated for 40,000 cycles at room temperature and 60°C., also without degradation of the resin.

One of the most disturbing features in the operation of exchange softeners in the past has been the gradual accumulation of dirt, calcium carbonate, magnesium hydroxide and iron hydrates on the softening material, so that gradually the unit loses capacity, builds up pressure drop and leaks

* "Color throw" describes the discoloration of water when contacted with an ion-exchange material and indicates a slight solubility of the exchange material or of one of its constituents.

through calcium, magnesium and iron to the softened water. The same effects have been noted on the resinous exchangers when operated on turbid water over a period of years. No thorough method of cleaning silicate materials is known because of their instability to acid and alkali, but a simple acid cleaning has been shown to clean completely beds of the nuclear sulfonic acid resins. This cleaning may be done without removing the resin from the shell.

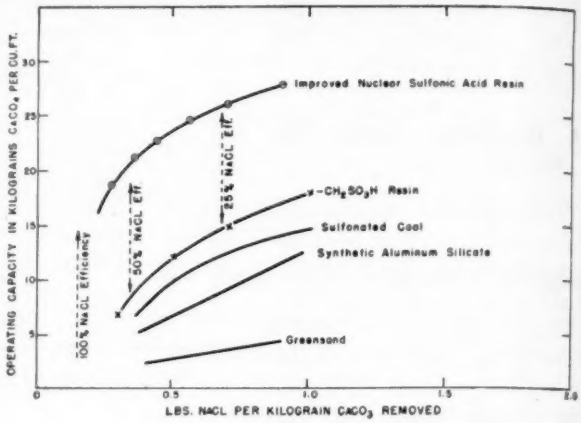

FIG. 4. Operating Capacity of Ion-Exchange Materials in Sodium Cycle

Thus it is practical to operate units of this resin in turbid raw water. A resin layer shows remarkable reduction in the turbidity. Raw water of 60–100-ppm. turbidity will be reduced to 15–25-ppm. turbidity, and sand filtered water of 10–15-ppm. turbidity is normally reduced to 2–3 ppm. Complete removal of turbidity may be obtained from a raw water supply of 100-ppm. turbidity by adding 20–25 ppm. alum to the feed of a resin unit. Color in water from industrial wastes and from decomposition of natural organic matter may be removed by the acid form of this sulfonic acid resin. It has been shown that a colored turbid raw water supply may be softened, clarified, decolorized and partially de-alkalized by proportioning alum and passing the water through a single bed of resin regenerated by a salt-acid mixture.

Hence, in the future it should be unnecessary to handle resins with "kid gloves," making them only an adjunct of a primary clarification and lime-soda softening plant. They can stand on their own feet as a single powerful means of purification of water and of altering the salt content of that water according to any specific needs.

With cation- and anion-exchange resins one has, in effect, tongs for picking up ionic constituents from solution, throwing them out completely or replacing them by other desirable ions. The time has passed when it is necessary to doctor up a water supply with added substances to blot out the effect of some undesirable ion. With the proper tongs one merely removes the core spot. Furthermore, if it is desired to add an ionic ingredient (for example potassium, phosphate or sulfite in boilers) to improve the water for some purpose, it is unnecessary to increase the total solids by adding a salt to the water—one merely substitutes this desirable ingredient for other ions present in the water by means of an exchange resin.

In the standard demineralization cycle three impurities in all surface water supplies are not removed: dissolved air, CO_2 and SiO_2. The first two may be eliminated by vacuum degasification or a standard de-aerator.

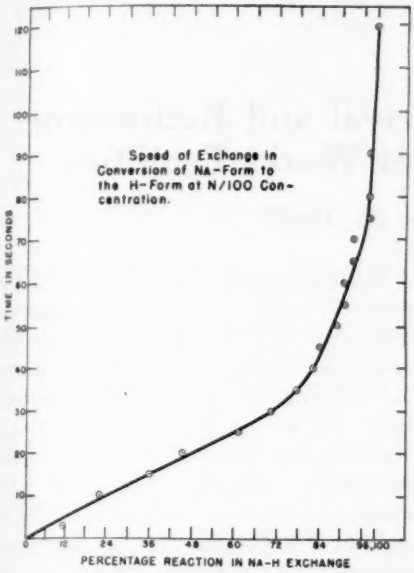
Speed of Exchange in Conversion of Na-Form to the H-Form at N/100 Concentration.
TIME IN SECONDS
PERCENTAGE REACTION IN NA-H EXCHANGE

FIG. 5. Speed of Exchange in Conversion of Na-Form to H-Form at N/100 Concentration in Improved Nuclear Sulfonic Acid Resin

Until recently the only method for silica removal was by adsorption by hydrates of magnesium, iron or aluminum. A hot process softener with excess magnesium hydrate will reduce the silica to 1–2 ppm., a value undesirably high for boiler feedwater when the remaining salts have been reduced to a comparable concentration. It has been found that this silica is readily removed by the standard demineralization cycle when fluoride is added.* In the acid conditions existing in the cation effluent the silica is rapidly converted by HF to H_2SiF_6, a strong acid readily absorbed by any of the anion-exchange resins. The non-ionic impurity has been converted to an ionic material which may be grasped with the ion-exchange tongs. By this method the silica may be reduced to less than 0.1 ppm., using from 130 to 160 per cent theoretical fluoride. This removes the last obstacle in producing pure H_2O from most natural water supplies by ion exchange. The extent of the salt removal depends merely on the proper design of equipment for the individual exchange materials used.

Central demineralization units in industrial plants will in the future supply pure water in service pipelines to all corners of the plant. No longer will it be necessary for the operators of the plants to trace the source of impurities in their product or variations in process control to the hardness, salt content, alkalinity or silica in their process water. They may be assured that they are receiving pure water—not just pure enough for drinking or for bathing, but actually the chemical H_2O of better than 99.999 per cent purity. And this chemical will usually cost less than 5¢ per ton, delivered on the spot.

* Patent applied for on this process.

Clyde, New York—Survival and Retirement Experience With Water Works Facilities

As of December 31, 1940

THE Clyde Plant of the Rochester & Lake Ontario Water Service Corporation renders water service in the village of Clyde and its environs in the town of Galen, Wayne County, located about 40 mi. east of Rochester, N.Y.

As of Dec. 31, 1940, the company furnished water to 538 customers in an area having a population of about 2,400. Sales during 1940 averaged about 0.073 mgd., or about 31 gpd. per capita.

Development of the Existing System

The Clyde Water Supply Company was incorporated in May 1888. The plant was constructed during 1888 and water service began in August 1889. In January 1928 the plant was purchased by the Federal Water Service Corporation, and, through merger, the property became the Clyde Plant of the Rochester & Lake Ontario Water Service Corporation. This corporation also furnished water service to suburban Rochester.

Originally the water supply was taken from the Clyde River. In 1891 a filter was installed but the supply continued to be unsatisfactory and was discontinued in 1902 and a new supply obtained from a shallow well. The well, brick-lined, is 13 ft. below ground level and extends 7 ft. above the ground, with dimensions 16 ft. id. by 20 ft. deep. The average yield in 1940 was 0.12 mgd.

The pumping station, located in the town of Galen, west of the corporate limits of Clyde, houses a steam-driven pump and boiler, motor-driven pump and chlorinators and auxiliary equipment. Water is chlorinated at the suction well and pumped directly into the distribution system. An open steel standpipe, 24 ft. in diameter by 60 ft. high, of 200,000-gal. capacity, furnishes storage and regulates pressures in Clyde.

At Dec. 31, 1940, there were approximately 10.5 mi. of ¾- to 10-in. mains, 31 valves and 89 fire hydrants in service. Services numbered 538, of which 499, or 93 per cent, were metered.

Basis of Study

The records of installation and retirement of cast-iron pipe, valves, hydrants and services are stated to be complete from the inception of the original company.

Mortality Survival Study

Mortality studies were made of cast-iron mains, valves, hydrants and services. Table 1 is a summary of cast-iron mains installed, retired and remaining in service, as well as average ages and sizes, lengths of records and mortality survival ratios. Figure 1 shows the mortality survival curves covering the amounts of pipe as shown.

Tables 2, 3, and 4 are similar summaries of gate valves, hydrants and

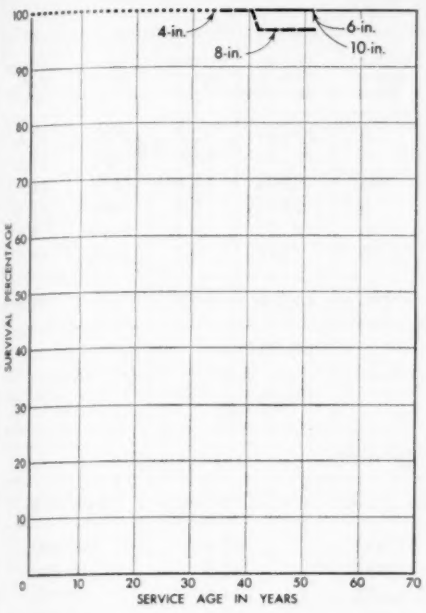

FIG. 1. Mortality Survival Curve—4–10-in. Cast-Iron Unlined Mains—Clyde, New York

BASE: Feet SURVIVAL: 1889–1940

SIZE *in.*	EXPOSURES *ft.*	RETIREMENTS *ft.*
4	22,951	0
6	11,533	0
8	6,574	200
10	1,025	0

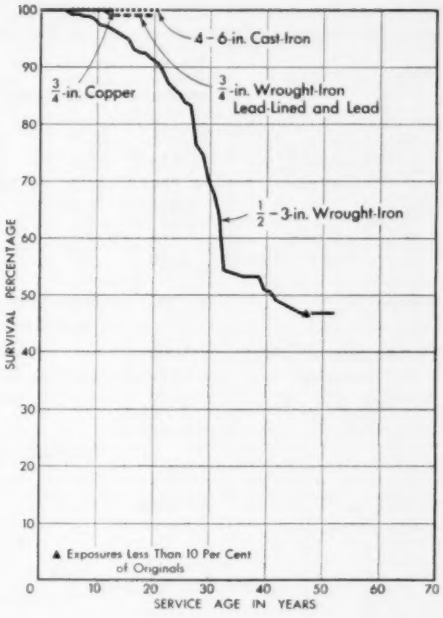
4 – 6-in. Cast-Iron
¾-in. Copper
¾-in. Wrought-Iron Lead-Lined and Lead
½ – 3-in. Wrought-Iron
▲ Exposures Less Than 10 Per Cent of Originals
SURVIVAL PERCENTAGE
SERVICE AGE IN YEARS

FIG. 2. Mortality Survival Curve—½–6-in. Services—Clyde, New York

BASE: UNIT SURVIVAL: 1889–1940

SIZE *in.*	KIND	EXPOSURES *Units*	RETIREMENTS *Units*
½–3	Wrought-Iron	603	189
¾	Wrought-Iron Lead-Lined and Lead	129	1
¾	Copper	92	0
4	Cast-Iron	1	0
6	Cast-Iron	2	0

services. As there were no retirements of valves or hydrants the mortality survival curves are straight lines at 100 per cent and are therefore not shown. Figure 2 shows the corresponding curves for services.

Causes of Retirement

The only retirement of pipe was, as is noted in Table 1, caused by a breakage under a bridge abutment.

No classification of the causes of retirement of services could be made. In many cases it was noted that services were replaced in advance of permanent concrete paving.

Acknowledgment

The collection and compilation of data for the study in the Clyde Plant were under the supervision of E. L. Heyser, Chief Valuation Engineer, New York Water Service Corporation.

TABLE 1

Summary of Mains

Clyde, New York

Size, *in.*	Kind	No. of Feet Installed	Percentage of Total	No. of Feet Retired	Percentage of Total	No. of Feet in Service	Percentage of Total	Year of First Installation	Average Age, *yr.*
4	Cast-iron unlined	22,951	51.5	0	0	22,951	51.7	1889	33.6
6		11,533	25.9	0	0	11,533	26.0	1889	51.5
8		6,574	14.7	200*	100	6,374	14.4	1889	51.5
10		1,025	2.3	0	0	1,025	2.3	1889	51.5
6	Cast-iron cement-lined	2,271	5.1	0	0	2,271	5.1	1929	8.8
8		246	0.5	0	0	246	0.5	1930	10.5
TOTAL		44,600	100.0	200	100	44,400	100.0		39.8
Percentage of Total		100.00		0.45		99.55			
Average Size, *in.*		5.37		8.00		5.36			

Mortality Survival Ratios

Size, *in.*	Kind	No. of Feet	Period Covered, *yr.*	Percentage
4	Cast-iron unlined	22,951	51.5	100.000
6		11,533	51.5	100.000
8		6,574	51.5	96.958
10		1,025	51.5	100.000
6 and 8	Cast-iron cement-lined	2,517	11.5	100.000
TOTAL		44,600		

* Retired and abandoned in place due to break under bridge abutment.

TABLE 2

Summary of Valves

Clyde, New York

Size, *in.*	Number Installed	Number Retired	Number in Service	Year of First Installation	Average Age, *yr.*
4	6	0	6	1889	22.8
6	15	0	15	1889	48.4
8	8	0	8	1889	48.1
10	2	0	2	1889	51.5
TOTAL	31	0	31		43.6
Percentage of Total	100.00	0	100.00		

Mortality Survival Ratios

Size, *in.*	Number Installed	Period Covered, *yr.*	Percentage
4–10	31	51.5	100.000
TOTAL	31		

TABLE 3

Summary of Hydrants
Clyde, New York

Size, *in.*	Kind	Number Installed	Number Retired	Number in Service	Year of First Installation	Average Age, *yr.*
4	(2) 2½-in. nozzle	82	0	82	1889	38.3
4	(2) 2½-in. and (1) steamer nozzle	8	0	8	1889	45.5
Total		90	0	90		38.9
Percentage of Total		100.00	0	100.00		

Mortality Survival Ratios

Size, *in.*	Kind	Number Installed	Period Covered, *yr.*	Percentage
4	All	90	51.5	100.000
Total		90		

TABLE 4

Summary of Services
Clyde, New York

Size, *in.*	Kind	Number Installed	Number Retired	Number in Service	Year of First Installation	Average Age, *yr.*
½	Wrought-iron	13	6	7	1890	49.5
¾	Wrought-iron	570	179	391	1889	29.2
1	Wrought-iron	10	1	9	1897	21.2
1¼	Wrought-iron	4	2	2	1890	13.0
1½	Wrought-iron	3	0	3	1894	27.2
2	Wrought-iron	2	1	1	1890	29.5
3	Wrought-iron	1	0	1	1914	26.5
¾	Wrought-iron lead-lined	10	0	10	1928	11.3
¾	Lead	119	1	118	1921	19.4
¾	Copper	92	0	92	1928	6.3
4	Cast-iron	1	0	1	1929	11.5
6	Cast-iron	2	0	2	1920	16.5
Total		827	190	637		23.8
Percentage of Total		100.00	22.97	77.03		

Mortality Survival Ratios

Size, *in.*	Kind	Number Installed	Period Covered, *yr.*	Percentage
½–3	Wrought-iron	603	51.5	46.789
¾ and ⅝	Wrought-iron lead-lined and Lead	129	19.5	99.187
¾	Copper	92	12.5	100.000
4–6	Cast-iron	3	20.5	100.000
Total		827		

Summary of Installations and Retirements
Clyde, New York

MAINS

4-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1889	3,318	3,318	0
1895	8,112	8,112	0
1914	884	884	0
1915	1,774	1,774	0
1917	1,328	1,328	0
1921	4,367	4,367	0
1922	886	886	0
1927	2,282	2,282	0
1940	0	0	0
Total	22,951	22,951	0

6-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1889	11,061	11,061	0
1890	472	472	0
1940	0	0	0
Total	11,533	11,533	0

8-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1889	6,574	6,374	200
1940	0	0	0
Total	6,574	6,374	200

8-in. Cast-Iron Unlined Mains (contd.)

Retirements by Years

Year Installed	Feet	Year
1889	200	1930

10-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1889	1,025	1,025	0
1940	0	0	0
Total	1,025	1,025	0

6-in. Cast-Iron Cement-Lined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1929	1,017	1,017	0
1931	496	496	0
1935	418	418	0
1937	340	340	0
1940	0	0	0
Total	2,271	2,271	0

8-in. Cast-Iron Cement-Lined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1930	246	246	0
1940	0	0	0
Total	246	246	0

VALVES

4-in. Valves

Year Installed	Number		
	Installed	In Service	Retired
1889	2	2	0
1927	2	2	0
1937	2	2	0
1940	0	0	0
Total	6	6	0

6-in. Valves

Year Installed	Number		
	Installed	In Service	Retired
1889	13	13	0
1890	1	1	0
1935	1	1	0
1940	0	0	0
Total	15	15	0

8-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1889	7	7	0
1916	1	1	0
1940	0	0	0
TOTAL	8	8	0

10-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1889	2	2	0
1940	0	0	0
TOTAL	2	2	0

HYDRANTS

4-IN. HYDRANTS—4-IN. CONNECTION, TWO HOSE NOZZLES

Year Installed	Number Installed	In Service	Retired
1890	1	1	0
1895	16	16	0
1914	2	2	0
1915	4	4	0
1917	3	3	0
1921	10	10	0
1922	2	2	0
1927	5	5	0
1940	0	0	0
TOTAL	43	43	0

4-IN. HYDRANTS—TWO HOSE AND ONE STEAMER NOZZLE

Year Installed	Number Installed	In Service	Retired
1895	1	1	0
1940	0	0	0
TOTAL	1	1	0

4-IN. HYDRANTS—4-IN. VALVE, 6-IN. CONNECTION, TWO HOSE NOZZLES

Year Installed	Number Installed	In Service	Retired
1889	34	34	0
1895	1	1	0
1929	3	3	0
1935	1	1	0
1940	0	0	0
TOTAL	39	39	0

4-IN. HYDRANTS—4-IN. VALVE, 6-IN. CONNECTION, TWO HOSE AND ONE STEAMER NOZZLE

Year Installed	Number Installed	In Service	Retired
1889	6	6	0
1931	1	1	0
1940	0	0	0
TOTAL	7	7	0

SERVICES

½-IN. WROUGHT-IRON SERVICES

Year Installed	Number Installed	In Service	Retired
1890	5	3	2
1891	1	1	0
1892	7	3	4
1940	0	0	0
TOTAL	13	7	6

Retirements by Years

Year Installed	Number	Year	Number	Year
1890	2	1921		
1892	2	1921	2	1923

¾-in. Wrought-Iron Services

Year Installed	Number Installed	In Service	Retired
1889	35	6	29
1890	12	2	10
1891	13	6	7
1892	25	5	20
1893	11	5	6
1894	85	44	41
1895	3	3	0
1896	10	4	6
1897	7	2	5
1898	4	2	2
1899	12	8	4
1900	15	7	8
1901	6	2	4
1902	5	3	2
1903	5	4	1
1904	3	1	2
1905	6	6	0
1906	2	1	1
1907	7	6	1
1908	14	9	5
1909	13	12	1
1910	7	5	2
1911	13	6	7
1912	14	13	1
1913	35	35	0
1914	24	21	3
1915	15	15	0
1916	15	12	3
1917	13	11	2
1918	10	9	1
1919	5	5	0
1920	7	7	0
1921	40	39	1
1922	13	13	0
1923	18	18	0
1924	23	20	3
1925	8	7	1
1926	5	5	0
1927	11	11	0
1928	1	1	0
1940	0	0	0
Subtotal	570	391	179
Unknown	82	0	82
Total	652	391	261

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1889	1	1896	1	1913	26	1921
	1	1933				
1890	1	1912	1	1913	1	1920
	7	1921				
1891	1	1912	5	1921	1	1933
1892	3	1913	11	1921	1	1922
	1	1923	3	1933	1	1937
1893	2	1915	3	1921	1	1933
1894	1	1910	1	1911	4	1913
	27	1921	1	1922	1	1928
	5	1933	1	1937		
1896	1	1912	3	1921	1	1922
	1	1926				
1897	1	1914	3	1921	1	1924
1898	2	1921				
1899	4	1921				
1900	1	1913	2	1921	1	1927
	3	1933	1	1935		
1901	3	1921	1	1933		
1902	1	1912	1	1921		
1903	1	1917				
1904	1	1911	1	1913		
1906	1	1921				
1907	1	1921				
1908	2	1921	2	1922	1	1936
1909	1	1923				
1910	1	1921	1	1922		
1911	5	1921	1	1927	1	1933
1912	1	1936				
1914	1	1922	1	1929	1	1935
1916	3	1921				
1917	1	1933	1	1935		
1918	1	1934				
1921	1	1936				
1924	1	1933	1	1934	1	1936
1925	1	1937				

1-IN. WROUGHT-IRON SERVICES

Year Installed	Number Installed	In Service	Retired
1897	1	1	0
1905	1	1	0
1914	1	1	0
1919	2	1	1
1920	1	1	0
1921	1	1	0
1926	1	1	0
1935	1	1	0
1937	1	1	0
1940	0	0	0
TOTAL	10	9	1

Retirements by Years

Year Installed	Number	Year
1919	1	1935

1¼-IN. WROUGHT-IRON SERVICES

Year Installed	Number Installed	In Service	Retired
1890	1	0	1
1904	1	0	1
1926	1	1	0
1929	1	1	0
1940	0	0	0
SUBTOTAL	4	2	2
Unknown	3	0	3
TOTAL	7	2	5

Retirements by Years

Year Installed	Number	Year
1890	1	1911
1904	1	1929

1½-IN. WROUGHT-IRON SERVICES

Year Installed	Number Installed	In Service	Retired
1894	1	1	0
1913	1	1	0
1933	1	1	0
1940	0	0	0
TOTAL	3	3	0

2-IN. WROUGHT-IRON SERVICES

Year Installed	Number Installed	In Service	Retired
1890	1	0	1
1911	1	1	0
1940	0	0	0
SUBTOTAL	2	1	1
Unknown	2	1	1
TOTAL	4	2	2

Retirements by Years

Year Installed	Number	Year
1890	1	1911

3-IN. WROUGHT-IRON SERVICES

Year Installed	Number Installed	In Service	Retired
1914	1	1	0
1940	0	0	0
TOTAL	1	1	0

¾-IN. WROUGHT-IRON LEAD-LINED SERVICES

Year Installed	Number Installed	In Service	Retired
1928	4	4	0
1929	1	1	0
1930	4	4	0
1931	1	1	0
1940	0	0	0
TOTAL	10	10	0

⅝-IN. LEAD SERVICES

Year Installed	Number Installed	In Service	Retired
1921	108	107	1
1922	11	11	0
1940	0	0	0
SUBTOTAL	119	118	1
Unknown	1	0	1
TOTAL	120	118	2

Retirements by Years

Year Installed	Number	Year
1921	1	1933

¾-IN. COPPER SERVICES

Year Installed	Number		
	Installed	In Service	Retired
1928	2	2	0
1929	5	5	0
1930	4	4	0
1931	10	10	0
1932	1	1	0
1933	21	21	0
1934	9	9	0
1935	9	9	0
1936	10	10	0
1937	6	6	0
1938	3	3	0
1939	8	8	0
1940	4	4	0
TOTAL	92	92	0

4-IN. CAST-IRON SERVICES

Year Installed	Number		
	Installed	In Service	Retired
1929	1	1	0
1940	0	0	0
TOTAL	1	1	0

6-IN. CAST-IRON SERVICES

Year Installed	Number		
	Installed	In Service	Retired
1920	1	1	0
1928	1	1	0
1940	0	0	0
TOTAL	2	2	0

Huntington, West Virginia—Survival and Retirement Experience With Water Works Facilities

As of December 31, 1940

THE Huntington Water Corporation is a privately-owned company serving the city of Huntington, W.Va., and certain outlying territory, including the town of Barboursville. It also operates under contract and furnishes water to the Lawrence County Water Company, a subsidiary supplying the village of Chesapeake, Ohio, on the opposite bank of the Ohio River. The city of Huntington had a population of 78,836 in 1940 but the population served was about 84,000.

Huntington is located on the south bank of the Ohio River near the extreme western end of the state near the Kentucky line. The city was incorporated in 1871 and is an important commercial and industrial center. It lies on a broad level plain along the river and extends up into the hills beyond. In the late 1930's a flood wall was constructed which has relieved the city of the devastating effects of the periodic high waters of the Ohio to which it was formerly subjected.

As of Dec. 31, 1941, there were 18,957 consumers, 99.5 per cent of whom were served through meter measurement. There were 205 mi. of mains and the average daily pumpage was about 6 mil.gal., equivalent to 76 gpd. per capita. About 21.5 per cent of the water pumped was for industrial use.

Development of the Existing System

On Nov. 22, 1886, the city of Huntington granted a franchise to W. S. Kuhn and his associates in the American Water and Guarantee Company to construct, maintain and operate a water works to supply water to the city of Huntington and its inhabitants. This franchise was assigned to the Huntington Water Corporation, which was incorporated in December 1886.

Work on the construction of the plant was started immediately thereafter, and the water works was put in operation the latter part of 1887. The original plant consisted of a pumping station, 7 mi. of mains and a reservoir located on the distribution system.

In August 1885 the town of Central City passed an ordinance authorizing the same individuals to construct, maintain and operate a water works to supply that town. The franchise was assigned to the Huntington Water Corporation which constructed the distribution system.

In 1888 the town of Guyandotte passed an ordinance granting to the same individuals a franchise to construct and operate a water works to supply the town of Guyandotte. A distribution system was constructed and put into operation in July 1888.

The original system in Guyandotte consisted of about 8,000 ft. of pipeline within the town limits and the original system in Central City consisted of over 3 mi. of pipeline within the limits of that town. Both Guyandotte and Central City secured their water supply from Huntington.

The town of Guyandotte became part of the city of Huntington on Apr. 11, 1911, and the town of Central City was included in Huntington by charter of the latter city in 1909.

The Huntington Water Corporation was incorporated in 1917 and the franchise of the Huntington Water Corporation and the Guyandotte Water Company were assigned to it, together with the rights to serve all of their respective territories.

In February 1929 the Huntington Water Corporation acquired all the property and business and franchise rights of the Barboursville Water and Light Company, supplying water service to the city of Barboursville located about 5 mi. east of Huntington. The Barboursville system was connected to the Huntington system by a pipeline extension of some 18,000 ft. of 8-in. cast-iron cement-lined pipe.

The territory, as now comprised, is about 12 mi. long and has a varying width with a maximum of 3 mi.

The American Water Works and Guarantee Company was a predecessor company of and became the American Water Works and Electric Company, Inc., in 1914. Since its original construction, therefore, the system, with the exception of the Barboursville and several minor areas, has been under one continuous ownership and management.

The original pump station of the Huntington Water Corporation was located on the bank of the Ohio River some twenty blocks east of the center of town. It consisted of a pump pit in which were located two 0.5-mil.gal. direct-acting steam pumps with suction lines extending into the Ohio River. Water was pumped by these pumps through pressure filters directly into the distribution system, which consisted of 7 mi. of pipe, as provided for in the original ordinance, with a 2.5-mil.gal. reservoir located on a high spot on a hill at the edge of the distribution system. A part of the original pump station and the reservoir are still in service. The elevation of the pump pit floor is 506 and the elevation of the reservoir overflow is 821.

It was soon demonstrated that the pressure filter system was a failure, as the untreated turbid water taken from the Ohio River quickly blocked the sand in the filters. The filter plant was abandoned and the water company, in an effort to supply its consumers with potable water, constructed a submerged crib in the bed of the river. This method was successful only a relatively short time, as the crib became clogged with fine sand and silt deposits. The company next installed a system of Cook wells in the sand bar in front of the pump station. This method of furnishing a clear water supply proved partly successful, but with continued use of the wells the yield decreased as the surface of the sand bed in which the wells were located gradually became clogged with silt and fine sand deposited by the river water.

For the last several years during which the well system constituted the principal source of supply, it became necessary more and more frequently to use untreated river water. This trouble continued until a gravity rapid sand filter plant, as well as a settling tank and necessary equipment for introducing coagulant into the water, was installed in 1899. At this time also, the original suction lines were replaced with new and larger suction lines extending to mid-channel. This prevented sand bars from forming and covering the strainers. The filter plant proved successful in operation from the

TABLE 1

SUMMARY OF MAINS
HUNTINGTON, WEST VIRGINIA

Size, in.	Kind	No. of Feet Installed	No. of Feet Identified	Percentage of Total	No. of Feet Retired	Percentage of Total	No. of Feet in Service	Percentage of Total	Year of First Installation	Average Age, yr.
4	Cast-iron unlined	12,643	12,643	1.2	0	0.0	12,643	1.3	1887	52.4
6		168,809	168,809	16.7	119	0.1	168,690	17.6	1887	34.3
8		126,219	126,219	12.0	144	0.2	126,075	13.2	1887	26.5
10		31,996	31,996	3.0	0	0.0	31,996	3.3	1887	39.3
12		58,607	58,607	5.6	199	0.2	58,408	6.1	1887	29.1
16		9,768	9,768	0.9	0	0.0	9,768	1.2	1906	24.7
20		4,469	4,469	0.4	0	0.0	4,469	0.5	1921	19.5
2	Cast-iron cement-lined	58,756	58,756	5.6	799	0.8	57,957	6.1	1929	3.5
6		4,764	4,764	0.4	0	0.0	4,764	0.5	1926	7.6
8		94,837	94,837	9.0	0	0.0	94,837	9.9	1925	11.1
12		30,071	30,071	2.9	0	0.0	30,071	3.1	1926	12.9
16		6,355	6,355	0.6	0	0.0	6,355	0.7	1927	13.5
20		2,796	2,796	0.3	0	0.0	2,796	0.3	1930	10.5
½	Galvanized steel	470	470	0.0	0	0.0	470	0.0	1920	20.5
¾		5,607	5,607	0.5	0	0.0	5,607	0.6	1920	6.9
1		15,762	15,670	1.4	4,304	4.6	11,366	1.2	1911	20.5
1¼		6,376	6,376	0.6	0	0.0	6,376	0.7	1911	20.6
1½		4,109	4,109	0.4	355	0.4	3,754	0.4	1911	20.9
2		259,542	251,160	23.9	32,985	35.2	218,175	22.8	1911	19.4
2½		185	185	0.0	0	0.0	185	0.0	1911	29.5
3		1,376	1,376	0.1	235	0.3	1,141	0.1	1911	14.1
4		2,064	2,064	0.2	0	0.0	2,064	0.2	1920	18.5
12		444	444	0.0	0	0.0	444	0.0	1923	17.5
¾	Galvanized wrought-iron	367	246	0.0	246	0.3	0	0.0	1888	—
1		2,566	2,310	0.2	2,082	2.2	228	0.0	1887	34.0
1¼		396	396	0.0	195	0.2	201	0.0	1888	29.5
1½		3,355	3,166	0.3	2,796	3.0	370	0.0	1887	43.2
2		150,289	142,768	13.5	47,877	51.2	94,891	9.9	1887	31.8
2½		185	185	0.0	0	0.0	185	0.0	1911	29.5
3		1,273	1,273	0.1	1,213	1.3	60	0.0	1904	29.5
1¼	Black wrought-iron	160	160	0.0	0	0.0	160	0.0	1926	14.5
2	Black wrought-iron	1,676	1,676	0.2	0	0.0	1,676	0.2	1926	14.5
1	Lead	418	418	0.0	0	0.0	418	0.0	1920	18.6
8	Talbot unwrapped	486	486	0.0	0	0.0	486	0.1	1930	10.5
TOTAL		1,067,196	1,050,635	100.0	93,549	100.0	957,086	100.0		23.8
Percentage of Total			100.00		8.90		91.10			
Average Size, *in.*			5.35		1.95		5.68			

TABLE 1 (contd.)

Mortality Survival Ratios

Size, *in.*	Kind	No. of Feet	Period Covered, *yr.*	Percentage
½–1½	All	38,928	52.5	11.106
4	Cast-iron unlined	12,643	53.5	54.293
6	Cast-iron unlined	168,809	53.5	100.000
8	Cast-iron unlined	126,219	53.5	99.837
10 and 12	Cast-iron unlined	90,603	53.5	99.803
Over 12	Cast-iron unlined	14,237	34.5	100.000
2	Cast-iron cement-lined	58,756	11.5	96.517
6 to 20	Cast-iron cement-lined	138,823	15.5	100.000
12	Galvanized steel	444	17.5	100.000
2 to 4	Wrought-iron and galvanized steel	400,687	52.5	54.293
8	Talbot unwrapped	486	10.5	100.000
TOTAL		1,050,635		

start and the city of Huntington and the other communities served have been furnished with filtered water since 1899.

The filter plant was added to from time to time as the increase in water consumption required, and in 1930 the original four wooden filter tubs were replaced. The filter plant has increased in capacity from the original 2-mgd. capacity in 1899 to a nominal 9-mgd. capacity at the present time.

The sedimentation facilities originally installed as part of the purification system consisted of small wooden tanks. These were later replaced by two large steel tanks, and later a concrete basin of 1-mil.gal. capacity was installed. The original steel settling tanks are now used as pre-sedimentation and grit chamber tanks.

In 1923, because of pollution entering the Ohio River from sewerage outfalls discharging into the Guyan River (which originally marked the boundary line between Huntington and Guyandotte), it became advisable to move the intake facilities to a point on the Ohio River about 3 mi. above the original station at 24th Street.

There was constructed on the bank of the river an intake chamber of reinforced concrete, 33 ft. × 26 ft. × 78½ ft. high. The interior is divided into a pump room and a wet chamber. The wet chamber is divided into two sections by a reinforced concrete wall and equipped with box screens over the pump suctions. The top of the pit extends well above record high water. From this point a 24-in. cast-iron pipeline was laid to the main station called the 24th Street Station.

The pumping equipment at the new station, known as the Guyandotte Low Service Station, consists of vertical motor-driven centrifugal pumps which delivered the water through the 24-in. line to the 24th Street Station, discharging into the steel tanks from which the water flows by gravity to the concrete sedimentation basin and thence to the filters. From the filters it goes to a clear well and is pumped directly into the distribution system.

In this same year the original pump

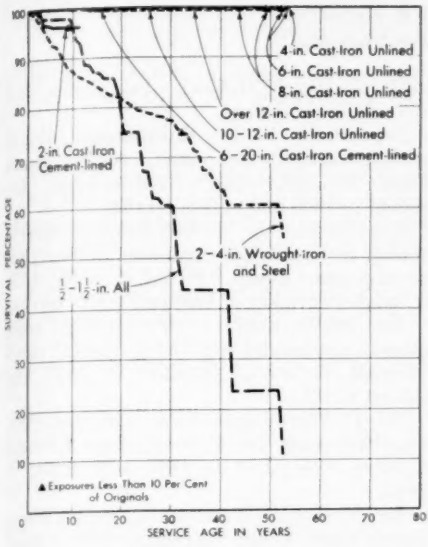

FIG. 1. Mortality Survival Curve—½–20-in. Mains—Huntington, West Virginia

BASE: Feet SURVIVAL: 1887–1940

SIZE	KIND	EXPOSURES	RETIREMENTS
in.		*ft.*	*ft.*
½–1½	All	38,928	9,978
2–4	Wrought-Iron and Steel	400,687	82,310
2	Cast-Iron Cement-Lined	58,756	799
6–20		138,823	0
4	Cast-Iron Unlined	12,643	0
6		168,809	119
8		126,219	144
10–12		90,603	199
Over 12		14,237	0

station and filter buildings at the 24th Street Station were replaced or veneered with new tapestry brick buildings and greatly enlarged, and at the same time, four 1-mgd. rapid sand concrete filters were added.

As the city grew there was extensive development on the hills to the south of town and elevations to be served from the general service necessitated the installation of two booster stations with elevated storage tanks.

Basis of Study

The installations and retirements of pipe were compiled from a study made for the purpose of listing all pipe that had been retired over the life of the property. The study was made coincidently with an inventory of existing mains. Company records were substantially complete as to size, kind and date of installation over the entire plant life. Existing retirement records were checked and supplemented by checking pipe installed with the pipe existing in specific locations.

Mortality Survival Study

Mortality studies of mains only were made. Table 1 is a summary of the pertinent information relative to the pipe systems. Figure 1 shows the mortality survival curves covering the amount, types and sizes of pipe grouped as shown.

A brief summary of Class B facilities covering wells, purification plant, pumping facilities and distribution reservoirs, tanks and standpipes is given below.

Causes of Retirement

There is no satisfactory record from which could be determined the causes of the retirement of mains.

Acknowledgment

The collection and compilation of data pertaining to the Huntington Water Corporation were carried out by the personnel of the American Water Works and Electric Company, Inc.

Summary of Class B Facilities
Huntington, West Virginia

Wells

Barboursville Wells

No. 1—Drilled 8-in. well, 63 ft. deep; steel cased, 8-in. strainer, 10 ft. long, pumped by plunger pump. Constructed in 1925 and still in service.

No. 2—Same as No. 1 except 59 ft. deep.

No. 3—Same as No. 1 except 55 ft. deep. Constructed in 1928 and still in service.

No. 4—Dug well, 3 ft. 6 in. square, 55 ft. deep; 15-in. diameter perforated steel casing, surrounded by gravel, pumped by centrifugal well pump. Constructed in 1928 and still in service.

Purification Works

Settling Tank—Wood tank, 30-ft. diameter by 16 ft. high; 85,000-gal. capacity. Constructed in 1898 and retired in 1913.

Settling Basin—Concrete basin, 85 ft. wide, 94.5 ft. long, 16 ft. deep; 900,000-gal. capacity. Constructed in 1922 and still in service.

Sedimentation Tank No. 1—Open steel riveted tank, 50-ft. diameter by 20 ft. high; 300,000-gal. capacity. Erected in 1904 and still in service.

Sedimentation Tank No. 2—Open steel riveted tank, 50-ft. diameter, 27.5 ft. high; 400,000-gal. capacity. Erected in 1913, top 4 ft. added in 1922, and still in service.

Original Filters—Four wood tub filters, 15-ft. diameter by 8 ft. high; 0.5-mgd. capacity each. Installed in 1899 and replaced in 1930 by steel tubs.

Steel Tub Filters—Ten steel tubs, 15-ft. diameter by 8 ft. high; 0.5-mgd. capacity each. First two installed in 1901, second two in 1906, third two in 1921 and last four in 1930; strainers in 1901 and 1906; tubs replaced in 1935; and still in service.

Concrete Filters—Four reinforced concrete, rapid sand, gravity filters, rated 1.0-mgd. capacity each. Constructed in 1923 and still in service.

Clear Water Basin—Rubble stone and concrete under filter house, 150,000-gal. capacity. Constructed in 1898 and still in service.

Pumping Equipment

24th Street Station

Low-Service No. 1—Hall direct-acting, vertical, compound, duplex, steam pump; 2.5-mgd. capacity, 85-ft. head. Installed in 1894 and still in service.

Low-Service No. 2—Worthington direct-acting, vertical, compound, duplex steam pump; 2.5-mgd. capacity, 104-ft. head. Installed in 1900 and still in service.

Low-Service No. 3—Worthington direct-acting, vertical, triple expansion, duplex, condensing steam pump; 5.0-mgd. capacity, 92.5-ft. head. Installed in 1906 and still in service.

No. 1—Worthington direct-acting, compound, non-condensing steam pump; rated 1.0-mgd. capacity. Installed in 1887 and retired in 1891.

No. 2—Worthington direct-acting, duplex, non-condensing steam pump; rated 1.5-mgd. capacity. Installed in 1887 and retired in 1900.

No. 3—Gordon direct-acting duplex steam pump; rated 2-mgd. capacity, 335-ft. head. Installed in 1892 and retired in 1894.

No. 4—Gordon direct-acting compound steam pump; rated 2-mgd. capacity. Installed in 1894 and retired in 1930.

High-Service No. 5—Worthington direct-acting, horizontal, compound, duplex, condensing steam pump; 2.5-mgd. capacity, 335-ft. head. Installed in 1898 and still in place but not used since 1939.

High-Service No. 6—Wood direct-acting, horizontal, triple expansion, duplex, condensing steam pump; 5.0-mgd. capacity, 300-ft. head. Installed in 1905 and still in service.

High-Service No. 7—LeCourtenay two single-stages in series, volute centrifugal pump driven through reduction gear by 346-hp. Terry steam turbine; rated 5.0-mgd. capacity at 315-ft. head. Installed in 1922 and still in service.

High-Service No. 8—Worthington two single-stages in series, volute centrifugal pump driven by 500-hp. synchronous motor; rated 7.0-mgd. capacity at 300-ft. head. Installed in 1931 and still in service.

Guyandotte Station

Low Service No. 1—Worthington single-stage centrifugal pump; rated 6.0-mgd. capacity at 103-ft. head, driven by 150-hp. induction motor. Installed in 1923 and still in service.

Low-Service No. 2—Same as No. 1 except rated 5.0-mgd. capacity at 94.5-ft. head.

Low-Service No. 3—DeLaval single-stage centrifugal pump; rated 8.0-mgd. capacity at

SUMMARY OF CLASS B FACILITIES (contd.)

35-ft. head, driven by 100-hp. synchronous motor. Installed in 1930 and still in service.

Barboursville Station

Well No. 1—Fairbanks Morse centrifugal pump installed in 1917, and Cook vertical plunger pump installed in 1925; belt driven by 50-hp. Bessemer gas engine. Installed in 1917 and still in service.

Well No. 2—Cook vertical plunger pump belt driven by above engine. Installed in 1925 and still in service.

Well No. 3—Same as above except installed in 1928.

Well No. 4—Peerless deep well pump, rated 400-gpm. capacity at 60-ft. head, driven by 10-hp. motor. Installed in 1928 and still in service.

High-Service—Dayton-Dowd two-stage centrifugal pump; rated 200-gpm. capacity at 180-ft. head, driven by 20-hp. motor. Installed in 1917 and still in service.

Ritter Hill Booster Station

No. 1—American Marsh four-stage centrifugal pump; rated 100-gpm. capacity at 276-ft. head, driven by 25-hp. induction motor. Installed in 1925 and still in service.

No. 2—Worthington two-stage centrifugal pump; rated 400-gpm. capacity at 276-ft. head, driven by 60-hp. induction motor. Installed in 1925 and still in service.

Roland Park Booster Station

Advance three-stage centrifugal pump; rated 100-gpm. capacity at 300-ft. head, driven by 25-hp. induction motor. Installed in 1925 and retired in 1935 and replaced by Goulds two-stage, 1-in. pump driven by 3-hp. motor, still in service.

Reservoirs, Tanks and Standpipes

Walnut Hill Reservoir—Open, earth embankment reservoir, bottom concrete paved, slopes lined with concrete and riprap; 140 ft. wide by 320 ft. long, 20 ft. deep; 2.5-mil.gal. capacity. Constructed in 1888 and still in service.

Shockey's Knob Standpipe—Covered steel standpipe, 16-ft. diameter, 60 ft. high; 100,000-gal. capacity. Erected in 1923 and still in service.

Roland Park Elevated Tank—Covered wood tank, 14-ft. diameter, 14 ft. high; 15,000-gal. capacity on 50-ft. steel tower. Erected in 1922 and still in service.

Barboursville Standpipe—Open steel standpipe, 42-ft. diameter, 19.5 ft. high; 200,000-gal. capacity. Erected in 1926 and still in service.

Summary of Installations and Retirements
Huntington, West Virginia

MAINS

4-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1887	4,153	4,153	0
1888	6,953	6,953	0
1889	550	550	0
1891	918	918	0
1916	69	69	0
1940	0	0	0
Total	12,643	12,643	0

6-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1887	14,063	14,063	0
1888	6,017	6,017	0
1889	250	250	0
1891	5,460	5,460	0
1892	4,464	4,464	0
1894	2,046	2,046	0
1895	6,134	6,118	16
1896	433	433	0
1898	1,871	1,871	0
1899	1,028	1,028	0
1900	2,893	2,893	0
1901	404	404	0
1902	2,098	2,098	0
1903	3,352	3,352	0
1904	2,962	2,962	0
1905	16,881	16,869	12
1906	10,867	10,867	0
1907	20,666	20,644	22
1908	3,999	3,999	0
1909	4,428	4,428	0
1911	8,187	8,118	69
1912	4,942	4,942	0
1913	1,561	1,561	0
1914	2,941	2,941	0
1915	2,237	2,237	0
1916	5,320	5,320	0
1917	1,842	1,842	0
1918	2,703	2,703	0
1919	389	389	0
1920	2,121	2,121	0
1921	2,954	2,954	0
1922	14,085	14,085	0
1923	2,264	2,264	0
1924	6,038	6,038	0

6-in. Cast-Iron Unlined Mains (contd.)

Year Installed	Feet Installed	Feet In Service	Feet Retired
1926	909	909	0
1940	0	0	0
Total	168,809	168,690	119

Retirements by Years

Year Installed	Feet	Year
1895	16	1939
1905	12	1940
1907	22	1937
1911	69	1933

8-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1887	5,933	5,933	0
1888	3,953	3,953	0
1891	4,175	4,175	0
1894	5,155	5,155	0
1902	1,906	1,834	72
1904	4,905	4,905	0
1905	2,717	2,717	0
1906	4,175	4,175	0
1907	2,513	2,513	0
1908	2,523	2,523	0
1910	5	5	0
1911	1,414	1,414	0
1912	9,034	9,034	0
1914	1,248	1,248	0
1915	230	230	0
1916	1,378	1,378	0
1917	8,437	8,437	0
1918	4,321	4,321	0
1920	747	747	0
1921	3,911	3,911	0
1922	4,785	4,785	0
1923	14,168	14,168	0
1924	23,903	23,903	0
1925	11,144	11,144	0
1926	836	764	72
1928	2,703	2,703	0
1940	0	0	0
Total	126,219	126,075	144

8-IN. CAST-IRON UNLINED MAINS (contd.)

Retirements by Years

Year Installed	Feet	Year
1902	72	1926
1926	72	1937

10-IN. CAST-IRON UNLINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1887	10,050	10,050	0
1894	3,457	3,457	0
1898	2,970	2,970	0
1910	485	485	0
1911	7,460	7,460	0
1912	3,037	3,037	0
1914	2,994	2,994	0
1918	820	820	0
1922	315	315	0
1923	408	408	0
1940	0	0	0
TOTAL	31,996	31,996	0

12-IN. CAST-IRON UNLINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1887	5,087	5,087	0
1898	9,081	9,081	0
1904	525	525	0
1911	6,662	6,662	0
1912	12,671	12,671	0
1914	1,463	1,431	32
1917	3,520	3,520	0
1919	522	522	0
1921	2,088	2,088	0
1922	3,849	3,775	74
1923	9,818	9,818	0
1924	1,721	1,721	0
1925	873	780	93
1926	727	727	0
1940	0	0	0
TOTAL	58,607	58,408	199

Retirements by Years

Year Installed	Feet	Year
1914	32	1937
1922	74	1938
1925	93	1937

16-IN. CAST-IRON UNLINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1906	1,749	1,749	0
1912	3,646	3,646	0
1921	473	473	0
1923	3,900	3,900	0
1940	0	0	0
TOTAL	9,768	9,768	0

20-IN. CAST-IRON UNLINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1921	4,469	4,469	0
1940	0	0	0
TOTAL	4,469	4,469	0

2-IN. CAST-IRON CEMENT-LINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1929	876	876	0
1930	2,551	2,551	0
1931	3,685	3,685	0
1932	1,285	1,285	0
1933	720	720	0
1934	364	364	0
1935	2,247	2,217	30
1936	5,131	5,131	0
1937	6,912	6,143	769
1938	12,238	12,238	0
1939	13,484	13,484	0
1940	9,263	9,263	0
TOTAL	58,756	57,957	799

Retirements by Years

Year Installed	Feet	Year
1935	30	1940
1937	769	1940

6-IN. CAST-IRON CEMENT-LINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1926	1,292	1,292	0
1927	192	192	0
1928	876	876	0
1933	108	108	0

6-IN. CAST-IRON CEMENT-LINED MAINS (contd.)

Year	Feet		
Installed	Installed	In Service	Retired
1934	144	144	0
1937	310	310	0
1939	16	16	0
1940	1,826	1,826	0
TOTAL	4,764	4,764	0

8-IN. CAST-IRON CEMENT-LINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1925	6,276	6,276	0
1926	28,992	28,992	0
1927	8,520	8,520	0
1928	8,301	8,301	0
1929	6,144	6,144	0
1930	8,760	8,760	0
1831	5,232	5,232	0
1932	7,464	7,464	0
1833	1,475	1,475	0
1934	24	24	0
1937	1,173	1,173	0
1938	9,411	9,411	0
1939	1,020	1,020	0
1940	2,045	2,045	0
TOTAL	94,837	94,837	0

12-IN. CAST-IRON CEMENT-LINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1926	11,424	11,424	0
1927	7,824	7,824	0
1928	7,608	7,608	0
1929	1,512	1,512	0
1937	658	658	0
1938	1,045	1,045	0
1940	0	0	0
TOTAL	30,071	30,071	0

16-IN. CAST-IRON CEMENT-LINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1927	6,336	6,336	0
1930	19	19	0
1940	0	0	0
TOTAL	6,355	6,355	0

20-IN. CAST-IRON CEMENT-LINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1930	2,796	2,796	0
1940	0	0	0
TOTAL	2,796	2,796	0

½-IN. GALVANIZED STEEL MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1920	470	470	0
1940	0	0	0
TOTAL	470	470	0

¾-IN. GALVANIZED STEEL MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1920	800	800	0
1926	50	50	0
1929	54	54	0
1934	193	193	0
1935	2,618	2,618	0
1936	661	661	0
1937	123	123	0
1938	459	459	0
1939	649	649	0
1940	0	0	0
TOTAL	5,607	5,607	0

1-IN. GALVANIZED STEEL MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1911	125	125	0
1915	1,117	0	1,117
1917	62	62	0
1920	14,205	11,018	3,187
1927	161	161	0
1940	0	0	0
SUBTOTAL	15,670	11,366	4,304
Unknown	92	0	92
TOTAL	15,762	11,366	4,396

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1915	1,117	1927		
1920	1,133	1939	2,054	1940

1¼-in. Galvanized Steel Mains

Year Installed	Feet		
	Installed	In Service	Retired
1911	201	201	0
1920	5,960	5,960	0
1926	215	215	0
1940	0	0	0
Total	6,376	6,376	0

1½-in. Galvanized Steel Mains

Year Installed	Feet		
	Installed	In Service	Retired
1911	150	150	0
1920	3,959	3,604	355
1940	0	0	0
Total	4,109	3,754	355

Retirements by Years

Year Installed	Feet	Year
1920	355	1940

2-in. Galvanized Steel Mains

Year Installed	Feet		
	Installed	In Service	Retired
1911	2,541	2,241	300
1914	34,687	26,357	8,330
1915	13,670	10,489	3,181
1916	9,603	7,499	2,104
1917	9,122	4,812	4,310
1918	1,776	1,205	571
1919	7,827	6,048	1,779
1920	39,877	38,451	1,426
1921	24,151	20,071	4,080
1922	14,655	13,325	1,330
1923	22,419	19,824	2,595
1924	8,838	8,453	385
1925	19,461	19,292	169
1926	19,627	19,627	0
1927	6,197	6,197	0
1928	12,583	10,435	2,148
1929	277	0	277
1930	1,099	1,099	0
1931	22	22	0
1932	252	252	0
1933	1,495	1,495	0
1934	981	981	0
1940	0	0	0
Subtotal	251,160	218,175	32,985
Unknown	8,382	0	8,382
Total	259,542	218,175	41,367

2-in. Galvanized Steel Mains (contd.)

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1911	179	1936	79	1937	42	1938
1914	51	1914	50	1916	338	1917
	1,270	1918	830	1921	2,931	1922
	1,235	1923	1,116	1924	222	1926
	287	1927				
1915	277	1917	814	1921	703	1922
	897	1923	150	1925	340	1927
1916	1,170	1921	163	1922	330	1924
	441	1927				
1917	1,417	1921	1,685	1922	723	1923
	342	1927	143	1931	356	1919
	215	1924				
1918	356	1919	215	1924		
1919	870	1923	273	1926	560	1927
	76	1937				
1920	197	1922	426	1923	642	1924
	161	1927				
1921	218	1922	990	1924	266	1925
	201	1926	1,406	1930	187	1937
	812	1940				
1922	1,098	1924	37	1926	195	1936
1923	791	1924	668	1925	157	1927
	122	1936	857	1940		
1924	385	1927				
1925	155	1937	14	1939		
1928	483	1933	1,665	1938		
1929	277	1940				

2½-in. Galvanized Steel Mains

Year Installed	Feet		
	Installed	In Service	Retired
1911	185	185	0
1940	0	0	0
Total	185	185	0

3-in. Galvanized Steel Mains

Year Installed	Feet		
	Installed	In Service	Retired
1911	235	0	235
1924	686	686	0
1930	455	455	0
1940	0	0	0
Total	1,376	1,141	235

Retirements by Years

Year Installed	Feet	Year
1911	235	1940

4-IN. GALVANIZED STEEL MAINS

Year Installed	Feet Installed	In Service	Retired
1920	1,860	1,860	0
1940	204	204	0
TOTAL	2,064	2,064	0

12-IN. GALVANIZED STEEL MAINS

Year Installed	Feet Installed	In Service	Retired
1923	444	444	0
1940	0	0	0
TOTAL	444	444	0

¾-IN. GALVANIZED WROUGHT-IRON MAINS

Year Installed	Feet Installed	In Service	Retired
1888	246	0	246
1940	0	0	0
SUBTOTAL	246	0	0
Unknown	121	0	121
TOTAL	367	0	367

Retirements by Years

Year Installed	Feet	Year
1888	246	1940

1-IN. GALVANIZED WROUGHT-IRON MAINS

Year Installed	Feet Installed	In Service	Retired
1887	106	0	106
1888	253	0	253
1891	283	0	283
1898	806	0	806
1899	48	0	48
1901	308	103	205
1902	341	0	341
1911	165	125	40
1940	0	0	0
SUBTOTAL	2,310	228	2,082
Unknown	256	0	256
TOTAL	2,566	228	2,338

1-IN. GALVANIZED WROUGHT-IRON MAINS (contd.)

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1887	106	1898				
1888	253	1898				
1891	283	1903				
1898	345	1900	250	1909	211	1924
1899	48	1927				
1901	205	1925				
1902	232	1912	109	1916		
1911	40	1930				

1¼-IN. GALVANIZED WROUGHT-IRON MAINS

Year Installed	Feet Installed	In Service	Retired
1888	195	0	195
1911	201	201	0
1940	0	0	0
TOTAL	396	201	195

Retirements by Years

Year Installed	Feet	Year
1888	195	1898

1½-IN. GALVANIZED WROUGHT-IRON MAINS

Year Installed	Feet Installed	In Service	Retired
1887	20	0	20
1888	2,304	220	2,084
1889	417	0	417
1900	275	0	275
1911	150	150	0
1940	0	0	0
SUBTOTAL	2,166	370	2,796
Unknown	189	0	189
TOTAL	3,355	370	2,985

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1887	20	1898				
1888	326	1891	797	1898	377	1904
	82	1912	100	1919	402	1930
1889	417	1903				
1900	135	1931	140	1932		

2-IN. GALVANIZED WROUGHT-IRON MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1887	575	0	575
1888	5,085	2,217	2,868
1889	820	0	820
1891	1,988	50	1,938
1892	2,989	1,419	1,570
1894	296	0	296
1895	541	253	288
1896	2,470	220	2,250
1898	1,312	428	884
1899	745	421	324
1900	3,097	2,474	623
1901	2,326	1,271	1,055
1902	4,787	3,765	1,022
1903	4,887	3,158	1,729
1904	7,678	5,526	2,152
1905	5,137	4,300	837
1906	4,293	1,928	2,365
1907	9,696	6,228	3,468
1908	5,761	3,494	2,267
1909	4,809	2,440	2,369
1910	9,668	4,556	5,112
1911	20,543	16,107	4,436
1912	8,136	7,371	765
1913	22,817	17,749	5,068
1916	7,499	5,272	2,227
1917	4,813	4,244	569
1940	0	0	0
SUBTOTAL	142,768	94,891	47,877
Unknown	7,521	0	7,521
TOTAL	150,289	94,891	55,398

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1887	575	1898				
1888	1,372	1891	300	1901	134	1903
	440	1910	372	1922	250	1940
1889	820	1912				
1891	412	1906	265	1907	265	1908
	220	1925	450	1927	326	1930
1892	528	1905	1,042	1923		
1894	70	1902	226	1930		
1895	288	1936				
1896	512	1900	410	1911	444	1912
	524	1932	360	1934		
1898	632	1905	252	1912		
1899	324	1906				
1900	323	1906	300	1911		
1901	321	1906	368	1922	366	1923
1902	65	1904	270	1907	396	1910
	91	1912	200	1937		
1903	673	1905	359	1906	28	1911
	200	1912	120	1924	349	1927
1904	934	1905	620	1924	146	1936

2-IN. GALVANIZED WROUGHT-IRON MAINS (contd.)

Retirements by Years (contd.)

Year Installed	Feet	Year	Feet	Year	Feet	Year
1904	452	1937				
1905	367	1905	259	1906	211	1922
1906	430	1907	206	1911	185	1915
	409	1922	250	1925	258	1931
	227	1937	400	1940		
1907	172	1907	378	1908	802	1911
	352	1912	429	1918	128	1921
	258	1922	668	1924	245	1934
	36	1940				
1908	225	1911	425	1912	480	1916
	912	1921	225	1923		
1909	400	1911	739	1912	444	1917
	456	1923	250	1924	80	1938
1910	1,025	1912	1,792	1917	428	1918
	355	1921	282	1922	140	1924
	345	1927	360	1928	210	1935
	175	1937				
1911	225	1917	1,473	1918	795	1923
	167	1924	1,210	1926	180	1927
	86	1930	300	1932		
1912	182	1917	195	1923	120	1924
	268	1926				
1913	225	1916	1,520	1917	1,584	1918
	460	1921	666	1923	75	1924
	235	1931	303	1940		
1916	1,091	1936	251	1937	608	1938
	277	1939				
1917	97	1937	472	1940		

2½-IN. GALVANIZED WROUGHT-IRON MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1911	185	185	0
1940	0	0	0
TOTAL	185	185	0

3-IN. GALVANIZED WROUGHT-IRON MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1904	1,038	0	1,038
1911	235	60	175
1940	0	0	0
TOTAL	1,273	60	1,213

Retirements by Years

Year Installed	Feet	Year
1904	1,038	1911
1911	175	1940

1¼-IN. BLACK WROUGHT-IRON MAINS

Year	Feet		
Installed	*Installed*	*In Service*	*Retired*
1926	160	160	0
1940	0	0	0
TOTAL	160	160	0

2-IN. BLACK WROUGHT-IRON MAINS

Year	Feet		
Installed	*Installed*	*In Service*	*Retired*
1926	1,676	1,676	0
1940	0	0	0
TOTAL	1,676	1,676	0

1-IN. LEAD MAINS

Year	Feet		
Installed	*Installed*	*In Service*	*Retired*
1920	75	75	0
1924	50	50	0
1925	228	228	0
1926	65	65	0
1940	0	0	0
TOTAL	418	418	0

8-IN. TALBOT UNWRAPPED MAINS

Year	Feet		
Installed	*Installed*	*In Service*	*Retired*
1930	486	486	0
1940	0	0	0
TOTAL	486	486	0

Babylon, New York—Survival and Retirement Experience With Water Works Facilities

As of December 31, 1940

THE Babylon plant of the New York Water Service Corporation is a private plant serving water in the incorporated villages of Babylon and Lindenhurst, the communities of North and West Babylon and environments located in Suffolk County on Long Island, N.Y.

The communities served are largely residential in character. There are some small industries along the south shore of Long Island, a part of the New York Metropolitan area. Within the area, as of the date of the study, there were 1,751 services furnishing water to a population of 12,900. Sales of water during 1940 averaged 0.3 mgd. or about 23 gpd. per capita.

Development of the Existing System

A predecessor of the present company, the Sumpwams Water Works Company was incorporated on Dec. 19, 1892. Plant construction was started early in 1893 and the first water service was rendered in September 1893. In May 1930 control of the company was acquired by Francis W. Collins from whom the New York Water Service Corporation purchased it on June 24, 1930. In September 1930, the Sumpwams Water Works Com-

TABLE 1

SUMMARY OF MAINS

BABYLON, NEW YORK

Size, in.	Kind	No. of Feet Installed	Percentage of Total	No. of Feet Retired	Percentage of Total	No. of Feet in Service	Percentage of Total	Year of First Installation	Average Age, yr.
4	Cast-iron unlined	51,808	21.0	9	1.6	51,799	21.1	1893	27.6
6		137,307	55.7	449	81.9	136,858	55.6	1893	22.5
8		17,823	7.2	90	16.5	17,733	7.2	1893	29.0
10		22,274	9.0	0	0	22,274	9.0	1926	13.9
12		779	0.3	0	0	779	0.3	1926	12.8
4	Cast-iron cement-lined	30	0.0	0	0	30	0.0	1931	8.6
6		14,456	5.9	0	0	14,456	5.9	1930	4.4
8		1,393	0.6	0	0	1,393	0.6	1930	8.8
2		848	0.3	0	0	848	0.3	1930	9.8
TOTAL		246,718	100.0	548	100.0	246,170	100.0		22.0
Percentage of Total		100.00		0.22		99.78			
Average Size, *in.*		6.14		6.30		6.10			

TABLE 1 (contd.)

Mortality Survival Ratios

Size, *in.*	Kind	Number of Feet	Period Covered, *yr.*	Percentage
4	Cast-iron unlined	51,808	47.5	99.972
6		137,307	47.5	99.258
8		17,823	47.5	98.433
10 and 12		23,053	14.5	100.000
4–12	Cast-iron cement-lined	16,727	10.5	100.000
TOTAL		246,718		

TABLE 2

SUMMARY OF VALVES

BABYLON, NEW YORK

Size, *in.*	Number Installed	Number Retired	Number in Service	Year of First Installation	Average Age, *yr.*
4	84	1	83	1893	28.4
6	194	1	193	1893	21.3
8	29	1	28	1893	30.4
10	10	0	10	1926	14.0
12	4	0	4	1926	11.5
TOTAL	321	3	318		23.6
Percentage of Total	100.00	0.93	99.07		

Mortality Survival Ratios

Size, *in.*	Number Installed	Period Covered, *yr.*	Percentage
4	84	47.5	93.333
6	194	47.5	96.296
8	29	47.5	95.000
10 and 12	14	14.5	100.000
TOTAL	321		

pany was merged with and its property became the Babylon plant of the New York Water Service Corporation. This corporation, controlled by the Federal Water and Gas Corporation, owns a number of other plants on Long Island and in other parts of the state.

The company secures its supply from wells. The original supply works, known as the Smith Street station and located in the village of Babylon, consisted of four 8-in. wells, 60 ft. deep. It was installed in 1903 and had a combined average yield of 1.2 mgd. Four

TABLE 3

SUMMARY OF HYDRANTS
BABYLON, NEW YORK

Size, in.	Type	Number Installed	Number Retired	Number in Service	Year of First Installation	Average Age, yr.
4	Two 2½-in. nozzle	224	55	169	1893	18.0
4	Two 2½-in. and steamer nozzle	129	44	85	1926	10.9
5	Two 2½-in. nozzle	3	0	3	1932	6.2
5	Two 2½-in. and steamer nozzle	29	1	28	1926	10.7
TOTAL		385	100	285		15.1
Percentage of Total		100.00	25.97	74.03		

Mortality Survival Ratios

Size, in.	Number Installed	Period Covered, yr.	Percentage
4	353	46.5	9.030
5	32	14.5	94.445
TOTAL	385		

TABLE 4

CAUSES OF RETIREMENT OF MAINS
BABYLON, NEW YORK

Size, in.	Kind	Length, ft.	Life, yr.	Cause of Retirement	Salvage, ft.
4	Cast-iron unlined	9	22.5	Lowering main	9
		9			9
6	Cast-iron unlined	9	4.5	Old pump station abandoned	0
		10	9.5	Lowering main	10
		70	21.5	Canal cut through road	0
		80	34.5	Old pump station abandoned	0
		75	43.5	New bridge construction	0
		205	47.5	Old pump station abandoned	0
		449			10
8	Cast-iron unlined	90	34.5	Old pump station abandoned	0
		90			0
	TOTAL	548			19

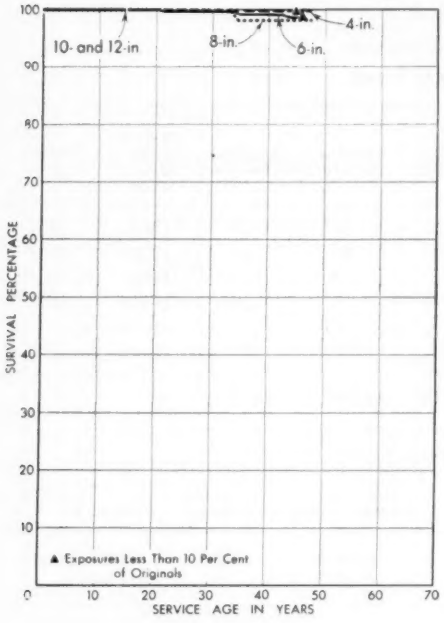

FIG. 1. Mortality Survival Curve—4–12-in. Cast-Iron Unlined Mains—Babylon, New York

BASE: Feet	SURVIVAL: 1893–1940	
SIZE	EXPOSURES	RETIREMENTS
in.	*ft.*	*ft.*
4	51,808	9
6	137,307	449
8	17,823	90
10 and 12	23,053	0

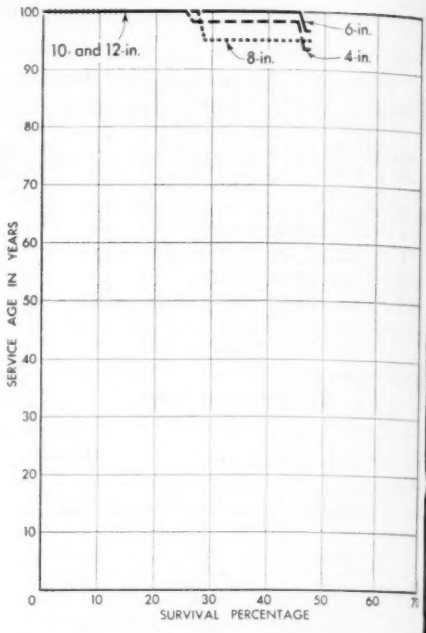

FIG. 2. Mortality Survival Curve—4–12-in. Valves—Babylon, New York

BASE: Unit	SURVIVAL: 1893–1940	
SIZE	EXPOSURES	RETIREMENTS
in.	*Units*	*Units*
4	84	1
6	194	1
8	29	1
10 and 12	14	0

additional 8-in. wells, having about the same yield, were installed in 1923.

Water was originally pumped from the wells into the distribution mains by three duplex steam pumps with steam furnished from two horizontal return tubular boilers. From 1927 until 1933 the Smith Street wells were held in reserve and at the later date the station and equipment were dismantled and retired. In 1940, however, the four newer wells were rehabilitated and a new pump station, housing two 300-gpm. at 200-ft. head motor-driven centrifugal pumps, was constructed and placed in service.

In 1927 a new pump station was built in the town of Babylon, known as the West Babylon pump station. This station has six 8-in. wells, 52 ft. deep, with a 20-ft. screen, having a combined average yield of 2.0 mgd. Water is pumped from the wells to the distribution system by two 8-in. centrifugal pumps in series. These are rated 2,000 gpm. at a 240-ft. head and are driven by a 200-hp. diesel engine, or by a two-stage 650-gpm. centrifugal

pump driven by a 65-hp. gasoline engine.

The distribution system contains a 300,000-gal. elevated steel tank erected in 1931 in Babylon.

As of Dec. 31, 1940, there were in service approximately 51.75 mi. of pipe, from 1 to 12 in. in diameter, largely of Class B cast-iron pipe; 366 valves and 285 fire hydrants. Services numbered 1,751 approximately 75 per cent of which were metered.

Basis of Study

The records of installation and retirement of cast-iron pipe, valves and hydrants are substantially complete from the beginning of the original company.

Mortality Survival Study

Mortality studies were made of cast-iron mains, valves and hydrants. Table 1 is a summary of cast-iron mains installed, retired and remaining in service, as well as their average ages, average sizes, lengths of records and mortality survival ratios. Figure 1 shows the mortality survival curves covering the above record.

Tables 2 and 3 are similar summaries of gate valves and hydrants with Figs. 2 and 3 representing the corresponding mortality survival curves.

Causes of Retirement

The causes of the retirements of mains, valves and hydrants are shown in Tables 4, 5 and 6, respectively.

It may be noted that the major cause of retirement of mains was the abandonment of a pumping station. It may further be noted that an important reason for retirement of hydrants was non-renewal of fire hydrant contracts. While from an accounting standpoint such may properly be a retirement, from a strict mortality standpoint it properly should not be classed as a fulfillment of the life of such facility.

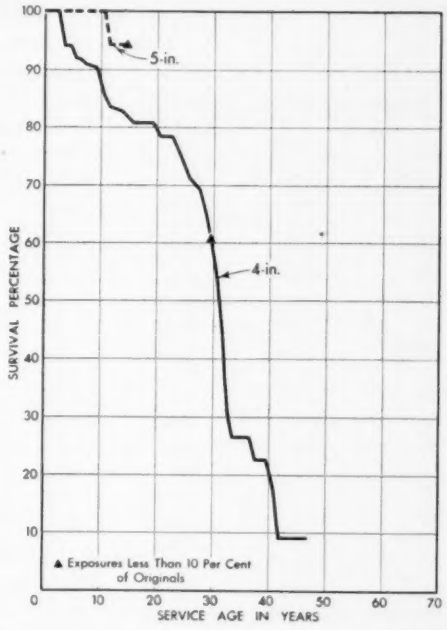

FIG. 3. Mortality Survival Curve—4- and 5-in. Hydrants—Babylon, New York

BASE: Unit SIZE	SURVIVAL: 1893–1940 EXPOSURES	RETIREMENTS
in.	*Units*	*Units*
4	353	99
5	32	1

Acknowledgment

The collection and compilation of data for the study in the Babylon plant were under the supervision of E. L. Heyser, Chief Valuation Engineer, New York Water Service Corporation.

TABLE 5

CAUSES OF RETIREMENT OF VALVES
BABYLON, NEW YORK

Size, *in.*	Number	Life, *yr.*	Cause of Retirement	Number Salvaged
4	1	46.5	Broken	0
	–			–
	1			0
6	1	46.5	Broken	0
	–			–
	1			0
8	1	28.5	Broken	0
	–			–
	1			0
	TOTAL 3			0

TABLE 6

CAUSES OF RETIREMENT OF HYDRANTS
BABYLON, NEW YORK

Number	Cause of Retirement	Salvaged
2	Leaking	0
7	Hit by automobile and broken	1
11	Relocated	5
43	Village contract not renewed	43
37	No reason	—
TOTAL 100		49

Summary of Installations and Retirements
Babylon, New York

MAINS

4-in. Cast-Iron Unlined Mains

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1893	2,392	2,392	0
1895	1,271	1,271	0
1896	2,008	2,008	0
1897	498	498	0
1898	1,200	1,200	0
1899	4,198	4,198	0
1900	348	348	0
1901	1,884	1,884	0
1902	1,014	1,014	0
1903	864	864	0
1904	384	384	0
1906	1,309	1,309	0
1907	1,046	1,046	0
1909	932	932	0
1910	2,423	2,423	0
1911	2,050	2,050	0
1912	4,911	4,902	9
1913	938	938	0
1914	1,937	1,937	0
1916	548	548	0
1920	360	360	0
1923	3,826	3,826	0
1924	749	749	0
1926	3,574	3,574	0
1927	1,309	1,309	0
1928	5,761	5,761	0
1929	3,383	3,383	0
1930	691	691	0
1940	0	0	0
Total	51,808	51,799	9

Retirements by Years

Year Installed	*Feet*	*Year*
1912	9	1934

6-in. Cast-Iron Unlined Mains

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1893	11,829	11,469	360
1895	2,515	2,515	0
1896	1,774	1,774	0
1899	1,500	1,500	0

6-in. Cast-Iron Unlined Mains (contd.)

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1904	1,678	1,678	0
1906	515	515	0
1908	4,752	4,752	0
1909	829	829	0
1910	1,402	1,402	0
1911	3,067	3,067	0
1912	23,355	23,285	70
1913	1,139	1,139	0
1914	1,958	1,958	0
1915	911	911	0
1916	241	241	0
1922	990	990	0
1923	8,644	8,635	9
1924	2,088	2,088	0
1925	4,155	4,145	10
1926	19,685	19,685	0
1927	14,021	14,021	0
1928	18,393	18,393	0
1929	11,568	11,568	0
1930	298	298	0
1940	0	0	0
Total	137,307	136,858	449

Retirements by Years

Year Installed	*Feet*	*Year*	*Feet*	*Year*	*Feet*	*Year*
1893	80	1927	75	1936	205	1940
1912	70	1933				
1923	9	1927				
1925	10	1934				

8-in. Cast-Iron Unlined Mains

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1893	5,742	5,652	90
1912	5,815	5,815	0
1927	2,700	2,700	0
1928	2,910	2,910	0
1929	656	656	0
1940	0	0	0
Total	17,823	17,733	90

8-IN. CAST-IRON UNLINED MAINS (contd.)

Retirements by Years

Year Installed	*Feet*	*Year*
1893	90	1927

10-IN. CAST-IRON UNLINED MAINS

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1926	8,155	8,155	0
1927	14,119	14,119	0
1940	0	0	0
TOTAL	22,274	22,274	0

12-IN. CAST-IRON UNLINED MAINS

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1926	38	38	0
1927	449	449	0
1929	292	292	0
1940	0	0	0
TOTAL	779	779	0

4-IN. CAST-IRON CEMENT-LINED MAINS

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1931	21	21	0
1934	9	9	0
1940	0	0	0
TOTAL	30	30	0

6-IN. CAST-IRON CEMENT-LINED MAINS

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1930	894	894	0
1931	2,925	2,925	0
1932	350	350	0
1933	110	110	0
1934	55	55	0
1935	899	899	0
1936	251	251	0
1937	1,874	1,874	0
1938	1,833	1,833	0
1939	2,742	2,742	0
1940	2,523	2,523	0
TOTAL	14,456	14,456	0

8-IN. CAST-IRON CEMENT-LINED MAINS

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1930	31	31	0
1931	1,208	1,208	0
1936	96	96	0
1940	58	58	0
TOTAL	1,393	1,393	0

12-IN. CAST-IRON CEMENT-LINED MAINS

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1930	754	754	0
1931	37	37	0
1940	57	57	0
TOTAL	848	848	0

VALVES

4-IN. VALVES

Year	*Number*		
Installed	*Installed*	*In Service*	*Retired*
1893	15	14	1
1895	1	1	0
1896	2	2	0
1899	6	6	0
1901	3	3	0
1904	1	1	0
1906	1	1	0
1907	1	1	0
1909	2	2	0
1910	2	2	0
1911	2	2	0
1912	11	11	0
1913	4	4	0
1914	3	3	0
1916	1	1	0
1920	1	1	0
1923	8	8	0
1926	5	5	0
1927	3	3	0
1928	3	3	0
1929	2	2	0
1930	2	2	0
1931	1	1	0
1936	1	1	0
1937	2	2	0
1939	1	1	0
1940	0	0	0
TOTAL	84	83	1

4-IN. VALVES (contd.)

Retirements by Years

Year Installed	*Number*	*Year*
1893	1	1939

6-IN. VALVES

Year Installed	*Number*		
	Installed	*In Service*	*Retired*
1893	27	26	1
1895	4	4	0
1896	3	3	0
1904	1	1	0
1906	1	1	0
1908	6	6	0
1909	2	2	0
1910	2	2	0
1911	3	3	0
1912	22	22	0
1913	3	3	0
1914	2	2	0
1915	1	1	0
1922	1	1	0
1923	7	7	0
1924	2	2	0
1925	6	6	0
1926	19	19	0
1927	16	16	0
1928	22	22	0
1929	13	13	0
1930	1	1	0
1931	4	4	0
1932	1	1	0
1933	2	2	0
1935	2	2	0
1937	2	2	0
1938	4	4	0
1939	8	8	0
1940	7	7	0
TOTAL	194	193	1

Retirements by Years

Year Installed	*Number*	*Year*
1893	1	1939

8-IN. VALVES

Year Installed	*Number*		
	Installed	*In Service*	*Retired*
1893	11	11	0
1912	9	8	1
1927	4	4	0
1928	2	2	0
1929	1	1	0

8-IN. VALVES (contd.)

Year Installed	*Number*		
	Installed	*In Service*	*Retired*
1930	1	1	0
1940	1	1	0
TOTAL	29	28	1

Retirements by Years

Year Installed	*Number*	*Year*
1912	1	1940

10-IN. VALVES

Year Installed	*Number*		
	Installed	*In Service*	*Retired*
1926	5	5	0
1927	5	5	0
1940	0	0	0
TOTAL	10	10	0

12-IN. VALVES

Year Installed	*Number*		
	Installed	*In Service*	*Retired*
1926	1	1	0
1929	1	1	0
1930	1	1	0
1931	1	1	0
1940	0	0	0
TOTAL	4	4	0

HYDRANTS

4-IN. HYDRANTS—TWO HOSE NOZZLES

Year Installed	*Number*		
	Installed	*In Service*	*Retired*
1893	10	0	10
1894	10	1	9
1895	5	0	5
1896	3	1	2
1897	2	0	2
1898	1	0	1
1899	3	0	3
1901	3	1	2
1902	2	0	2
1904	4	4	0
1907	1	1	0
1908	4	2	2
1909	1	1	0
1910	1	1	0

4-IN. HYDRANTS—TWO HOSE NOZZLES (contd.)

Year Installed	Number Installed	In Service	Retired
1911	3	3	0
1912	13	12	1
1915	2	2	0
1916	3	3	0
1917	2	2	0
1920	1	1	0
1922	3	3	0
1923	41	32	9
1924	13	12	1
1925	29	27	2
1926	28	26	2
1927	6	5	1
1928	17	17	0
1929	6	5	1
1930	2	2	0
1932	1	1	0
1934	1	1	0
1937	1	1	0
1940	2	2	0
SUBTOTAL	224	169	55
Unknown	1	0	1
TOTAL	225	169	56

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1893	2	1923	1	1924	7	1925
1894	2	1923	2	1924	3	1925
	1	1934	1	1935		
1895	3	1923	1	1924	1	1928
1896	1	1929	1	1937		
1897	1	1917	1	1923		
1898	1	1935				
1899	1	1912	1	1924	1	1930
1901	2	1925				
1902	2	1925				
1908	1	1928	1	1933		
1912	1	1939				
1923	7	1928	2	1938		
1924	1	1938				
1925	2	1928				
1926	1	1933	1	1940		
1927	1	1937				
1929	1	1940				

4-IN. HYDRANTS—TWO HOSE NOZZLES AND ONE STEAMER NOZZLE

Year Installed	Number Installed	In Service	Retired
1926	2	2	0
1927	17	15	2

4-IN. HYDRANTS—TWO HOSE NOZZLES AND ONE STEAMER NOZZLE (contd.)

Year Installed	Number Installed	In Service	Retired
1928	58	32	26
1929	30	14	16
1930	5	5	0
1933	2	2	0
1934	4	4	0
1935	5	5	0
1937	2	2	0
1938	1	1	0
1939	1	1	0
1940	2	2	0
TOTAL	129	85	44

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1927	1	1934	1	1935		
1928	18	1931	1	1934	6	1939
	1	1940				
1929	1	1936	1	1938	14	1939

5-IN. HYDRANTS—TWO HOSE NOZZLES

Year Installed	Number Installed	In Service	Retired
1932	1	1	0
1935	1	1	0
1936	1	1	0
1940	0	0	0
TOTAL	3	3	0

5-IN. HYDRANTS—TWO HOSE NOZZLES AND ONE STEAMER NOZZLE

Year Installed	Number Installed	In Service	Retired
1926	1	1	0
1927	14	13	1
1928	1	1	0
1929	2	2	0
1931	5	5	0
1933	2	2	0
1937	2	2	0
1938	2	2	0
1940	0	0	0
TOTAL	29	28	1

Retirements by Years

Year Installed	Number	Year
1927	1	1938

Merrick, New York—Survival and Retirement Experience With Water Works Facilities

As of December 31, 1940

THE Merrick-Massapequa plant of the New York Water Service Corporation, a private utility, furnishes water service to the southern part of the town of Oyster Bay, including the communities of Merrick, North Merrick, Bellmore, North Bellmore, Wantagh, Seaford, Massapequa and environs, all lying in Nassau County, Long Island, adjacent to the New York City limits. The area served is predominately residential.

As of the date of the study the company served 3,500 customers, representing a population of about 21,000. Sales averaged 0.83 mgd., or about 39 gpd. per capita.

Development of the Existing System

The Merrick Water Company, serving the village of Merrick and surrounding area was incorporated in 1895. In April 1912, the Hempstead and Oyster Bay Water Company was incorporated and its directors and stockholders at their first meeting resolved to purchase the stock of the Merrick Water Company. The merger was consummated in July 1912, under the name of the Hempstead and Oyster Bay Water Company.

In February 1926, Francis W. Collins acquired control of the company. His interest was purchased in 1930 by the New York Water Service Corporation, a subsidiary of the present Federal Water & Gas Corporation, and the company became first the Merrick plant and later the Merrick-Massapequa plant of the New York Water Service Corporation.

The source of water supply has always come from wells. The original supply, developed in 1895, was located in the present village of Merrick and continued in use with the pumping station until 1923. A new supply, consisting of four wells and a pumping station, was constructed at this time in Merrick and continued in use until 1938, when two new driven wells, with a combined average yield of 1 mgd., were developed. These wells are 12 in. in diameter and approximately 45 ft. deep, with 8-in. drop pipes. The supply is pumped from the wells directly into the distribution system by two 750-gpm. centrifugal pumps driven by 50-hp. diesel oil engines installed in 1923 and 1924.

In 1928 a new supply was developed, with a Hart open well, 13 ft. in diameter, 18 ft. deep to a gravel fill which extends 21 ft. lower, in Massapequa. In 1936 a new gravel-pack well was developed adjacent to the Hart well. This well is 28 in. in diameter, 73 ft. deep, with casing to 42 ft. and an inner casing 16 in. in diameter, 43 ft. deep, with a 30-ft. strainer. The two wells have an average yield of approximately 1.73 mgd.

The Hart well is pumped by a 750-gpm. centrifugal pump belt driven by a

TABLE 1

SUMMARY OF MAINS

MERRICK, NEW YORK

Size, *in.*	Kind	Number of Feet Installed	Percentage of Total	Number of Feet Retired	Percentage of Total	Number of Feet in Service	Percentage of Total	Year of First Installation	Average Age, *yr.*
4	Cast-iron unlined	45,250	13.7	36*	21.8	45,214	13.7	1912	20.6
6		87,389	26.4	73†	44.3	87,316	26.4	1912	15.2
8		29,033	8.8	0	0	29,033	8.8	1922	13.7
12		61,349	18.6	56‡	33.9	61,293	18.6	1926	12.4
4	Cast-iron cement-lined	99	0.0	0	0	99	0.0	1931	5.7
6		70,998	21.5	0	0	70,998	21.5	1931	6.1
8		28,446	8.6	0	0	28,446	8.6	1931	7.9
10		49	0.0	0	0	49	0.0	1937	3.5
12		7,820	2.4	0	0	7,820	2.4	1931	8.5
TOTAL		330,433	100.0	165	100.0	330,268	100.0		12.5
Percentage of Total		100.00		0.05		99.95			
Average Size, *in.*		7.33		7.6		7.33			

Mortality Survival Ratios

Size, *in.*	Kind	Number of Feet	Period Covered, *yr.*	Percentage
4	Cast-iron unlined	45,250	28.5	99.823
6		87,389	28.5	99.916
8		29,033	18.5	100.000
12		61,349	14.5	99.909
4–12	Cast-iron cement-lined	107,412	9.5	100.000
	Total	330,433		

* 9 ft. retired at 8.5 years and 27 ft. at 24.5 years because of sewer construction. Salvaged.

† 9 ft. retired at 6.5 years, 39 ft. at 7.5 years and 25 ft. at 8.5 years because of sewer construction. Salvaged.

‡ 18 ft. retired at 5.5 years because valve installed. Salvaged. 38 ft. retired at 5.5 years because tee inserted. 36 ft. salvaged.

55-hp. diesel oil engine direct to the distribution system. This well also has installed a deep well pump of 440-gpm. capacity driven by a 25-hp. motor installed in 1931. The gravel-pack well is equipped with a low-lift deep well pump of 700-gpm. capacity and is driven by a 10-hp. electric motor installed in 1936. The pump discharges through a steel riffle-type aerator to a concrete clear water basin. A 700-gpm. centrifugal pump driven by a 40-hp. electric motor then takes its suction from the basin and pumps to the distribution system.

Water storage facilities in the system include an elevated steel tank 19 ft. in diameter by 17.5 ft. deep, with a capacity of 50,000 gal., which was erected in 1922; and another one 38 ft. in diameter by 17.5 ft. deep, with a capacity of 200,000 gal. erected in 1924

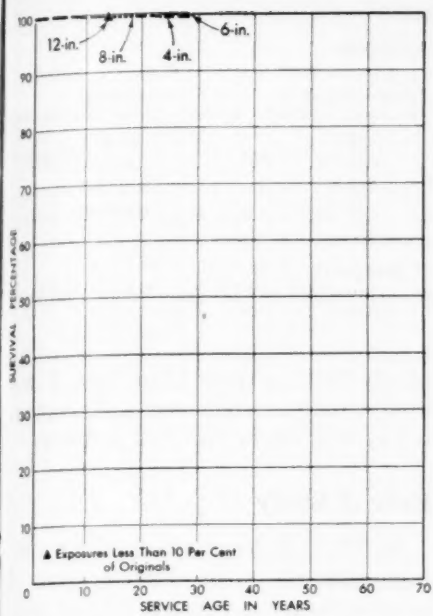

FIG. 1. Mortality Survival Curve—4–12-in. Cast-Iron Unlined Pipe—Merrick, New York

BASE: Feet	SURVIVAL: 1912–1940	
SIZE	EXPOSURES	RETIREMENTS
in.	*ft.*	*ft.*
4	45,250	36
6	87,389	73
8	29,033	0
12	61,349	56

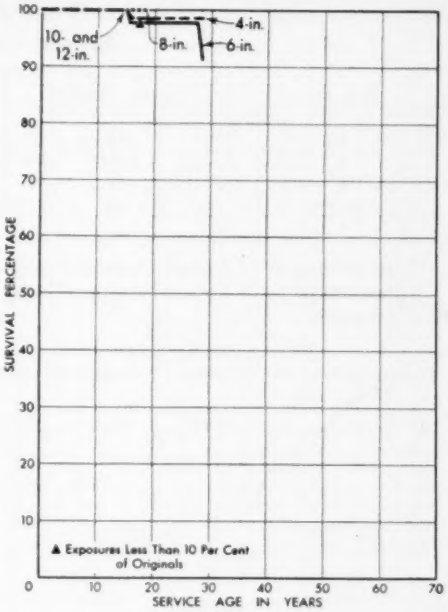

FIG. 2. Mortality Survival Curve—4–12-in. Valves—Merrick, New York

BASE: Unit	SURVIVAL: 1912–1940	
SIZE	EXPOSURES	RETIREMENTS
in.	*Units*	*Units*
4	82	1
6	295	2
8	74	0
10 and 12	70	0

TABLE 2

SUMMARY OF VALVES

MERRICK, NEW YORK

Size, *in.*	Number Installed	Number Retired	Number in Service	Year of First Installation	Average Age, *yr.*
4	82	1*	81	1912	18.8
6	295	2†	293	1912	10.7
8	74	0	74	1922	10.4
10	1	0	1	1937	3.5
12	69	0	69	1926	11.6
TOTAL	521	3	518		12.0
Percentage of Total	100.00	0.58	99.42		

TABLE 2 (contd.)

Mortality Survival Ratios

Size, *in.*	Number Installed	Period Covered, *yr.*	Percentage
4	82	28.5	98.413
6	295	28.5	90.881
8	74	18.5	100.000
10–12	70	14.5	100.000

* One retired at 15.5 years because of leaking. Scrapped.

† One retired at 28.5 years because of leaking and one retired at 15.5 years because broken. Both scrapped.

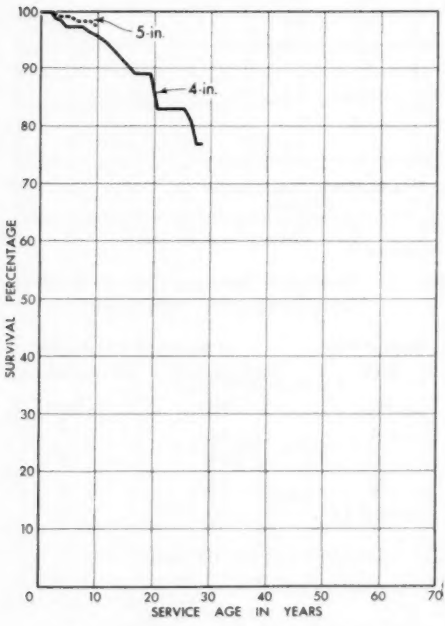

FIG. 3. Mortality Survival Curve—4- and 5-in. Hydrants—Merrick, New York

BASE: Unit SIZE	SURVIVAL: 1912–1940 EXPOSURES	RETIREMENTS
in.	*Units*	*Units*
4	388	36
5	228	4

Both tanks are located at the pump site in the village of Merrick.

The distribution system, as of the date of the study, consisted of approximately 78 mi. of ¾- to 12-in. pipe of cast iron, wrought iron, steel and copper. It has 449 valves and 576 hydrants.

Basis of Study

In 1913, under the terms of a contract with the town of Hempstead, it was necessary to replace a large portion of the original mains with pipe of larger size, to lay new mains and install fire hydrants. Available records of the Merrick Water Company do not give even a partially complete record of the original main installation.

This study is therefore confined to a study of mains, valves and hydrants installed and retired from 1912 to the date of the study.

Mortality Survival Study

The mortality survival study is confined to cast-iron mains, valves and hydrants installed since 1912. Table 1 is a summary of pipe installed, retired and still in service, as well as of other pertinent data relative to the cast-iron pipe. Figure 1 shows the mortality survival curves covering the grouping of mains shown.

Tables 2 and 3 show the summaries of valves and hydrants with Figs. 2 and 3 representing the corresponding mortality survival curves.

TABLE 3

SUMMARY OF HYDRANTS
MERRICK, NEW YORK

Size, in.	Kind	Number Installed	Number Retired	Number in Service	Year of First Installation	Average Age, yr.
4	Two 2½-in. Hose Nozzle	387	36	351	1912	14.4
4	Two 2½-in Hose and Steamer Nozzle	1	0	1	1939	1.5
5	Two 2½-in. Hose Nozzle	148	0	148	1931	7.1
5	Two 2½-in. Hose and Steamer Nozzle	80	4	76	1931	6.6
TOTAL		616	40	576		11.5
Percentage of Total		100.00	6.5	93.5		

Mortality Survival Ratios

Size, in.	Number Installed	Period Covered, yr.	Percentage
4	388	28.5	76.538
5	228	9.5	97.483
TOTAL	616		

NOTE: Majority of retirements were due to relocation, or damage by automobile and, after repair, generally set up again.

Causes of Retirement

The recorded causes of retirement of cast-iron pipe are shown in the footnote in Table 1. A similar footnote in Table 2 gives the reasons for the retirement of valves.

Acknowledgment

The collection and compilation of the data for the Merrick-Massapequa plant were under the general direction of E. L. Heyser, Chief Valuation Engineer, New York Water Service Corporation.

Summary of Installations and Retirements
Merrick, New York

Mains

4-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1912	14,558	14,531	27
1913	963	963	0
1915	1,684	1,684	0
1922	180	180	0
1923	3,167	3,167	0
1924	12,462	12,462	0
1925	6,076	6,067	9
1926	5,429	5,429	0
1927	10	10	0
1928	721	721	0
1940	0	0	0
Total	45,250	45,214	36

Retirements by Years

Year Installed	Feet	Year
1912	27	1936
1925	9	1933

6-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1912	9,924	9,924	0
1922	3,383	3,383	0
1924	6,256	6,256	0
1925	7,374	7,374	0
1926	3,343	3,343	0
1927	18,659	18,625	34
1928	26,422	26,414	8
1929	9,216	9,185	31
1930	2,812	2,812	0
1940	0	0	0
Total	87,389	87,316	73

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1927	9	1933	25	1935
1928	8	1935		
1929	31	1936		

8-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1922	710	710	0
1923	9,382	9,382	0
1924	266	266	0
1927	2,609	2,609	0
1928	4,695	4,695	0
1929	3,736	3,736	0
1930	6,835	6,835	0
1931	800	800	0
1940	0	0	0
Total	29,033	29,033	0

12-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1926	958	958	0
1927	7,176	7,176	0
1928	34,951	34,913	38
1929	18,225	18,207	18
1930	39	39	0
1940	0	0	0
Total	61,349	61,293	56

Retirements by Years

Year Installed	Feet	Year
1928	38	1933
1929	18	1934

4-in. Cast-Iron Cement-Lined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1931	14	14	0
1933	9	9	0
1935	43	43	0
1936	27	27	0
1939	6	6	0
1940	0	0	0
Total	99	99	0

6-IN. CAST-IRON CEMENT-LINED MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1931	31,511	31,511	0
1932	4,301	4,301	0
1933	2,137	2,137	0
1935	1,073	1,073	0
1936	6,487	6,487	0
1937	7,058	7,058	0
1938	2,631	2,631	0
1939	8,888	8,888	0
1940	6,912	6,912	0
TOTAL	70,998	70,998	0

8-IN. CAST-IRON CEMENT-LINED MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1931	21,607	21,607	0
1933	253	253	0
1936	2,398	2,398	0
1937	1,106	1,106	0
1938	342	342	0
1939	417	417	0
1940	2,323	2,323	0
TOTAL	28,446	28,446	0

10-IN. CAST-IRON CEMENT-LINED MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1937	49	49	0
1940	0	0	0
TOTAL	49	49	0

12-IN. CAST-IRON CEMENT-LINED MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1931	3,931	3,931	0
1932	3,049	3,049	0
1934	18	18	0
1937	822	822	0
1940	0	0	0
TOTAL	7,820	7,820	0

VALVES

4-IN. VALVES

Year Installed	Number		
	Installed	In Service	Retired
1912	22	22	0
1913	1	1	0
1915	3	3	0
1923	5	5	0
1924	21	21	0
1925	11	10	1
1926	10	10	0
1927	2	2	0
1928	1	1	0
1931	1	1	0
1939	4	4	0
1940	1	1	0
TOTAL	82	81	1

Retirements by Years

Year Installed	Number	Year
1925	1	1940

6-IN. VALVES

Year Installed	Number		
	Installed	In Service	Retired
1912	14	13	1
1922	3	3	0
1924	15	15	0
1925	15	14	1
1926	4	4	0
1927	33	33	0
1928	53	53	0
1929	27	27	0
1930	5	5	0
1931	50	50	0
1932	8	8	0
1933	4	4	0
1935	1	1	0
1936	9	9	0
1937	11	11	0
1938	5	5	0
1939	17	17	0
1940	21	21	0
TOTAL	295	293	2

6-IN. VALVES (contd.)

Retirements by Years

Year Installed	*Number*	*Year*
1912	1	1940
1925	1	1940

8-IN. VALVES

Year	*Number*		
Installed	*Installed*	*In Service*	*Retired*
1922	1	1	0
1923	7	7	0
1924	2	2	0
1927	3	3	0
1928	12	12	0
1929	7	7	0
1930	7	7	0
1931	23	23	0
1936	2	2	0
1937	6	6	0
1938	1	1	0
1940	3	3	0
TOTAL	74	74	0

10-IN. VALVES

Year	*Number*		
Installed	*Installed*	*In Service*	*Retired*
1937	1	1	0
1940	0	0	0
TOTAL	1	1	0

12-IN. VALVES

Year	*Number*		
Installed	*Installed*	*In Service*	*Retired*
1926	1	1	0
1927	9	9	0
1928	34	34	0
1929	16	16	0
1931	2	2	0
1932	2	2	0
1934	1	1	0
1937	4	4	0
1940	0	0	0
TOTAL	69	69	0

HYDRANTS

4-IN. HYDRANTS—TWO HOSE NOZZLES

Year	*Number*		
Installed	*Installed*	*In Service*	*Retired*
1912	40	34	6
1913	2	2	0
1915	3	3	0
1922	2	2	0
1923	22	21	1
1924	38	33	5
1925	27	22	5
1926	18	18	0
1927	59	56	3
1928	74	61	13
1929	42	41	1
1930	25	25	0
1931	8	6	2
1932	1	1	0
1933	5	5	0
1935	3	3	0
1936	2	2	0
1937	2	2	0
1938	1	1	0
1939	12	12	0
1940	1	1	0
TOTAL	387	351	36

4-IN. HYDRANTS—TWO HOSE NOZZLES (contd.)

Retirements by Years

Year Installed	*Number*	*Year*	*Number*	*Year*	*Number*	*Year*
1912	3	1932	1	1938	2	1939
1923	1	1939				
1924	3	1936	1	1937	1	1939
1925	1	1933	1	1935	2	1939
	1	1940				
1927	2	1931	1	1940		
1928	5	1931	1	1932	1	1935
	1	1936	1	1937	1	1939
	2	1939	1	1940		
1929	1	1931				
1931	1	1933	1	1939		

4-IN. HYDRANTS—TWO HOSE AND ONE STEAMER NOZZLE

Year	*Number*		
Installed	*Installed*	*In Service*	*Retired*
1939	1	1	0
1940	0	0	0
TOTAL	1	1	0

5-IN. HYDRANTS—TWO HOSE AND ONE STEAMER NOZZLE

Year Installed	Number Installed	In Service	Retired
1931	41	40	1
1932	7	6	1
1935	2	2	0
1936	2	1	1
1937	10	9	1
1938	4	4	0
1939	5	5	0
1940	9	9	0
TOTAL	80	76	4

Retirements by Years

Year Installed	Number	Year
1931	1	1940
1932	1	1938
1936	1	1938
1937	1	1939

5-IN. HYDRANTS—TWO HOSE NOZZLES

Year Installed	Number Installed	In Service	Retired
1931	83	83	0
1932	12	12	0
1933	2	2	0
1935	2	2	0
1936	12	12	0
1937	11	11	0
1938	4	4	0
1939	14	14	0
1940	8	8	0
TOTAL	148	148	0

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

INDUSTRIAL WATER SUPPLY

Two Debatable Questions Relating to Recirculation of Diffusion Water. H. CLAASSEN. Zuckerind. (Ger.) **1**: 129 ('43). Question discussed whether, in beet-sugar factories in which recirculation of waste waters practiced, different waste waters should be kept separate or should be mixed before recirculation. Many sugar technologists maint. preferable to keep diffusion water separate from condensate. Author showed in '06 that when press water, diffusion water and condensate kept separate and recirculated separately, extraction of sugar in later vessels of battery unsatisfactory. When condensate mixed with diffusion water, pH value of water increased. Corrosion of iron in plant in which diffusion water recirculated due to acid and sand in water; sand acts mechanically. Usually assumed that acids formed by bact. decompn. of sugars in water but author considers that they are produced from pectic substances in beet pulp. Deg. of corrosion differs considerably in different factories and in same factory in different years. Reason for these differences is varying compn. of beets. Pectic substances more easily dissolved from unripe beets or from beets which have received nitrogenous fertilizers than from ripe beets or from beets which have been fertilized with phosphates. Unripe or over-manured beets soft; during cutting process and during pressing of cossettes they yield more pulp, from which pectin more easily dissolved and decomposed, than do ripe beets. No attempt made to control corrosion by neutralizing acids by addn. of condensate contg. ammonia, because content of ammonia fluctuates. pH value must be maintd. which will not only prevent corrosion but which will have no deleterious effect on diffusion and on pressing of cossettes. Corrosion most serious in cossette process and in pumps. Addn. of alk. condensate alone not sufficient to prevent corrosion; milk of lime should be added at suitable points in plant before cossettes pressed.—*W.P.R.*

Cooling Water, a Chemical and Biological Problem. L. W. HAASE. Water. *A Yearbook for Water Chemistry and the Technic of Water Treatment.* **XV** ('41–'42). Verein Deutscher Chemiker. Verlag Chemie, G.m.b.H. (Ger.) ('42) 368 pp. Advantages and disadvantages of use as cooling water of ground water, surface water and tap water discussed. Formation of scale in cooling plants important, as even small deposit may reduce eff. of plant by 30% or more. Deposits of corrosion products do not prevent heat exchange to same deg. as does scale. Compn. of ground and surface waters and various types of treatment required to produce suitable cooling water described. Corrosion in cooling plants due to micro-organisms, removal from water of living and dead org. matter by coagulation and control of growth of micro-organisms discussed. Recirculated cooling water differs from cooling water not recirculated in that with continual use hardness decreases, total content of salts increases and carbon dioxide, oxygen, micro-organisms and suspended matter taken up from air. Recirculated water becomes strongly corrosive. Corrosion due to micro-organisms in recirculated surface water usually more severe than that due to micro-organisms in surface water that is not recirculated because temp. of former higher. Suspended matter taken up from air may cause corrosion of metal through formation of local elec. elements. To overcome these

difficulties recirculated cooling water should be filtered; one-tenth of water should pass every hour through filter which will remove carbon dioxide. Chlorination of water may be advantageous but must be applied cautiously to prevent lowering of pH value. Occasionally difficulties caused in cooling systems by entry of larvae of mussels and other lower organisms which attach themselves to pipes and develop into fully grown organisms.—*W.P.R.*

Process Water Used in the Manufacture of Fine Paper. L. B. MILLER. Paper Tr. J. **117**: TAPPI Sec. 279 ('43). Summary of part of Special Rpt. No. 333 published by TAPPI, giving information on qual. of raw waters and process waters used in mfr. of fine papers at 42 mills. Sources of waters include lakes, rivers and wells. Of 42 sources, 20 pold. by sewage or trade waste waters. Water untreated at only 1 mill. 2 mills apply mech. treatment only and rest apply either chem. treatment or both mech. and chem. treatment. Turbidity considered more important factor than color in production of high-grade paper; permissible upper limits of turbidity vary from 0 to 25 ppm. Only 5 mills set upper limit to content of dissolved solids in process waters; these limits vary from 75 to 150 ppm. Contents of iron in process waters vary from 0.06 to 58 ppm.; 7 mills use water contg. more than 0.3 ppm. iron. 5 mills set permissible upper limits to content of iron, which vary from 0.2 to 10.0 ppm. More than 0.3 ppm. iron, either dissolved or in suspension, colors high qual. paper; manganese has more detrimental effect than iron. Contents of manganese in process waters vary between trace and 7.0 ppm. None of mills sets upper limit to total hardness of process waters, 2 mills set limits to permanent hardness of 40 and 100 ppm. and 5 set limits to temporary hardness varying from 50 to 100 ppm. Total, permanent and temporary hardnesses of process waters vary from 35 to 405 ppm., from 20 to 130 ppm. and from 5 to 350 ppm., resp. Total hardness important in mfr. of paper because calcium and magnesium ions react with many materials used for sizing with production of substances which have little sizing value. Methyl orange alkalinities of process waters vary from 4 to 350 ppm.; 4 mills set upper limits for alky. of 150, 70, 50 and 7 ppm. pH values of process waters vary from 5.2 to 9.3. Hydrogen-ion concn. important in all stages of mfr. of paper. Sulfate and chloride have little effect on mfr. of paper unless present in high concns. Concns. of org. matter in process waters vary from 0 to 133 ppm.; 2 mills set upper limits of 0 and 20 ppm. for content of org. matter. Content of org. matter should generally be kept as low as possible. Contents of dissolved silica in process waters vary between 0.6 and 32 ppm.; 2 mills set upper limits of 22 and 30 ppm. dissolved silica. Silica not of great importance in mfr. of paper but should not be present in more than moderate amts.—*W.P.R.*

Experiences of a Paper Mill in Bacteriological Control. G. M. SUYDAM & R. R. MCCONKY. Paper Tr. J. **118**: TAPPI Sec. 67 ('44). To det. best means for producing paper with low bact. count for mfr. of food containers, bact. examn. of water and paper made in paper mill which obtains its water from Musconetcong R., N.J. After settlement, raw water treated with alum and lime, resettled and filtered through rapid sand filters. Operation and cleanliness of filters improved by chlorination of water before it entered filters; amt. of chlorine added gradually increased until residual concn. of 0.4 ppm. chlorine obtained in effluent from filters. Chloramine treatment next used in order to carry residual chlorine further through mill; although bact. conditions in water throughout mill improved, no reduction in number of bacteria in paper. Break-point chlorination of raw water produced tasteless, odorless water contg. few bacteria. For time number of bacteria in paper remained low but subsequently increased. Disinfection of broke and starch reduced numbers of bacteria in material supplied to beaters. In order to maint. low bact. counts in subsequent processes in mill some of chlorine introduced into pulp during bleaching allowed to remain; serious foaming occurred on paper machine under these conditions. Direct application of gaseous chlorine reduced but did not elim. foaming. Application of chlorine in soln. therefore adopted; same amt. of chlorine more effective when fed to head box and to stock diln. water than when added at one point only. When maint. of residual chlorine throughout system attempted only when paper for food containers being made, number of bacteria in paper increased for short period after chlorination introduced. When continuous chlorination of white water begun, at first considerable increase in numbers of

bacteria in paper but after 3 mo. numbers of bacteria lower than they had been when chlorination intermittent. During investigation special attention paid to condition of calender water because of danger of recontamn. of paper from this source. When mill water supply contained 0.5 ppm. chlorine water rechlorinated for calenders to give residual concn. of 2.0 ppm. chlorine and water boxes and pulp dams soaked in bleach liquor. With this treatment inlet water sterile but bacteria developed in boxes as temp. of water increased and chlorine liberated as gas. Source of water therefore changed to condensate from drying cylinders; condensate cooled and chlorine and ammonia added. Air used to cool calender rolls filtered. Effluent from boxes now sterile but no reduction in number of bacteria in finished paper observed. Use of chlorinated condensate discontinued when break-point chlorination of mill water introduced because possible to maint. residual concn. of chlorine in boxes if sufficiently high rate of flow maintd. to prevent development of high temp. and consequent liberation of chlorine as gas. No correlation observed between number of bacteria in calender water and number of bacteria in finished paper. Nevertheless, when paper for food containers being mfd. only filtered mill water used in calendering process, not only because of danger of bact. contamn. but also because recirculated calender solns. can impart tastes and odors to paper. Bacteria most commonly found in water and in finished paper aerobic spore-forming bacteria; some of these bacteria not killed by heating to 100° C. for 1 hr. and would therefore not be destroyed in driers. Most predominant types *B. megatherium* and variety of *B. mycoides*.—*W.P.R.*

Water Quality and Water Treatment in Industry in Relation to Water Source. L. W. HAASE. Pumpen- u. Brunnenbau, Bohrtech. (Ger.) 164, 183 ('42); Wasser u. Abwasser (Ger.) **40**: 151 ('42). Old or true ground water characterized by lack of oxygen, org. matter, and bacteria and by presence of reduced nitrogen and metal compds., excess CO_2 and H_2S. Easily treated by aeration and filtration to remove Fe, Mn and CO_2. Young ground water contains considerable org. matter and oxidized metals. Treatment similar to that for surface water which it resembles; chlorination or treatment with ozone suggested.—*C.A.*

Purification of Water, As in Pure Ice Production From Sea Water. WILLIS R. WHITNEY (to Gen. Elec. Co.). U.S. 2,340,721 (Feb. 1, '44). Describes app. and method of operation employed for producing substantially pure solvent component from soln. This involves projecting jet of soln. while at temp. approx. its fp. into contact with surface maintd. at temp. sufficiently low to cause portion of liquid component to freeze on it. Thus stream of excess soln. so distributed over surface of frozen component as to cause it to be washed continually, and veloc. of this stream maintd., with respect to rate of freezing, sufficiently high to prevent occlusion of impurities in frozen component. —*C.A.*

Research Brings Better Railroading. ANON. Railway Age **118**: 18: 794 (May 5, '45). Norfolk and Western Ry.'s avg. annual expenditure and use of $20,000,000 of materials and supplies (excluding fuel and new equip.) controlled by research, anals. and tests. From 7500 mil.gal. of water treated in 69 water treating plants during '44, nearly 12,000,000 lb. of scale-forming matter removed before delivery to locomotives. Lime, soda ash and sodium aluminate used at 20 large softening plants while 9 different chem. compds. used at 49 "wayside" plants. Dissolved solids checked regularly by conductivity tests and colloidal type treatment has greatly increased critical foaming concn., resulting in marked reduction in blowdown. Tests of raw, treated and boiler water samples checked frequently by 3 water service supervisors.—*R. C. Bardwell.*

Increasing the Capacity of Water Facilities to Meet Demands of Heavier Traffic. GUY E. MARTIN. Ry. Eng. & Maint. **40**: 11:1028 (Nov. '44). Large increase in tonnage and train miles on railways since Dec. '41 has created serious problem in maintg. adequate water supply for locomotives at terminals where consumption has increased from 30 to 40%. Where city supplies inadequate has been necessary to develop other sources. General lowering of ground water levels in many parts of country has resulted in decreased production requiring addnl. wells or reconditioning. Many reservoirs have been cleaned and addnl. roadside tanks installed. Mains cleaned, addnl. lines installed and water columns overhauled to permit delivery of 4500 gpm. Operation of softening plants

which were being worked over capac. improved by recirculation or continuous agitation of sludge. Change in pumping plant equip. to automatic operation has proven helpful in many cases.—*R. C. Bardwell.*

High-Speed Watering Facilities for Streamline Trains. A. W. JOHNSON ET AL. Am. Ry. Eng. Assn. **46**: 448: 64 (Nov. '44). Majority of railroads use 1" hydrants with from 60 to 150' of hose for delivering water to passenger cars. Diesel locomotive watering facilities have hydrants from 2 to 4" using 2½" hose with delivery from 200 to 400 gpm.—*R. C. Bardwell.*

New York Central Locomotives Scoop Water Without Reducing Speed. ANON. Ry. Age **117**: 4: **149**. New York Central RR. has developed and is installing newly designed scoops on engine tanks which permit taking water from track pans at speeds up to 80 mph. Water waste reduced to 27.5% at 60 mph. and 21.5% at 75 mph. which is point of max. eff. Details effecting improvement concerned with directing flow and properly venting tank.—*R. C. Bardwell.*

The Ice Industry. PHILIP W. WEST. Chem. & Eng. News **22**: 718 (May 10, '44). Annual ice production is 34,000,000 tons from about 4000 plants. Source of fresh water ice must conform to U.S.P.H.S. stds. Water may be obtained by distn. or from raw water, treated as required. Crystallization effects some purif. since natural ice clear in first several inches slowly frozen at surface. Quickly frozen, artificial ice traps impurities, thereby forming opaque blocks unless agitated to conc. solids in core. Core water, generally amtg. to 10% of original vol., replaced by fresh water and freezing resumed to yield a more transparent block. Opacity forms either as white shell during initial minutes of freezing when with ordinary aeration dissolved salts do not diffuse rapidly enough from fluid film on crystal interfaces, or as white cake from concn. of salts or by pptn. of $CaCO_3$ after alky. reaches 1200 to 1400 ppm. Up until about 25 hr. during freezing naturally occurring CO_2 decreases due to aeration; beyond this point CO_2 increases by conversion of bicarbonates to carbonates. Opacity preventable by reducing initial solids or removal of bicarbonate alky. with alum or acid. Shattering or cracking in ice frozen at low temp. may be caused by expansion strains when removed from freezing brine, by warped cans, poor brine circulation and inclusions within cake when $CaCO_3$ pptd. Inclusions prevented by softening water or by anti-crack compounds, such as ammonium chloride, which increase soly. of $CaCO_3$. Presence of free CO_2 for initial hours of freeze, introduced through glass frits, forms crack-resistant ice and permits lower brine temps. and increases production. Carbonation often helpful when CO_2 naturally deficient or following lime softening. Mineralization of water affects ice adversely, usual limits in total solids varying between 150 to 300 ppm. With auxiliary air feed waters as high as 1300 ppm. dissolved solids successfully frozen. Calcium bicarbonate forms inclusions and so-called sand in drain pipes. Magnesium bicarbonate gives greenish color; sodium bicarbonate less troublesome than calcium bicarbonate. High sulfate concn. causes white shells and butts. Org. exchange filters, through demineralization of waters high in sodium compds., extend choice of raw waters. Upflow treatment units with sludge blanket, by producing clear and stable effluents, improve can water prepn.—*A. A. Hirsch.*

The Use of Water in Refrigeration and Air-Conditioning. IRVING REICHMAN. Jour. A.S.R.E. 113 (Feb. '44). New conservatory and protective regulations in New York City for refrigeration and air-conditioning equip., using municipally-supplied water, provide for issue of permit, method of metering, restriction of waste to 5 gpm. or installation of economizer, evaporative condenser or cooling tower that must restrict consumption of water to 15% or less of normal use otherwise. Chief use of water is for refrigerant cooling or condensing medium; in air-conditioning also used for washing, cooling and dehumidification of air. In ice plants water needed incidently for air cooling, thawing, filter washing, etc. Quant. of water required for condensing compressed refrigerant gas influenced by inlet water temp., veloc. of flow, refrigerant condensing and suction temps., condenser design and properties of refrigerant. Make-up water to offset losses in continuous recirculation devices due to evapn., drift and purging usually applied through float-controlled inlet on collecting pan. This demand depends on incoming air, wet bulb temp. and veloc. that removes surrounding vapor. Recirculation through evaporators reduces CO_2 and increases pH and alky. of

New York water. With such water and clean atmosphere continuous purging ordinarily unwarranted. Purging does not control microbiol. slimes; for this condition draining and scrubbing with chem. in recirculation effective. At 90° F. evapn. of spray water in tower approxs. 0.03 gpm. per ton refrigerating capac. On sultry days with wet bulb above 78° evapn. slight, so operator uses supplementary city water or bypasses cooling tower entirely. Mfr. of can ice described.—*A. A. Hirsch.*

TASTE AND ODOR CONTROL

New Taste Control Treatment To Be Used in Lindsay, Ont. A. E. BERRY. Wtr. & Sew. **83**: 2: 21 (Feb. '45). Mathieson Alkali Works, Inc., have developed procedure that makes possible use of powerful oxidizing agent, chlorine dioxide, for taste destruction. Process used at Tonawanda, North Tonawanda, Lockport, Western New York Water Co., Niagara Falls, N.Y., and Chicopee, Mass. In Niagara Falls there are 2 rapid sand filter plants of 10- and 32-mgd. capac., resp. Water pre-chlorinated (usually 1.5 ppm.) to give residual of 0.4–0.5 ppm. in settling basin and 0.2 ppm. in filter effluent. Chlorine dioxide, which is unstable and must be produced at point of use, generated by introducing sodium chlorite soln., prepd. in earthenware crocks or coated metal tanks, into dischg. line of chlorinator in proportion of 1:1 (dry wts. of chlorine and chlorine dioxide), mixt. passing through small glass-enclosed mixing chamber into clear well. Treatment effective for both phenolic and algal tastes, destruction being very rapid. Dosage at 2 plants 1.6–1.7 and 2.5 lb. sodium chlorite per mil.gal. Treatment may be applied at any point but economy effected by oxidizing org. matter first by pre-chlorination, as price of flake sodium chlorite 75¢ lb. Cost for continuous use approx. equal to that for activated C. No more difficult to apply than Cl and excess chem. apparently has no injurious effects. Plans made to expt. with treatment at Lindsay, where weedy taste due to algae in slow-moving river troublesome.—*R. E. Thompson.*

Taste and Odor Problems at Winnipeg. W. D. HURST. Eng. Cont. Rec. **57**: 30: 8 (July 26, '44). Source of supply Shoal Lake, arm of Lake of the Woods, 100 mi. from city. Lake shallow and shores and bed of hard Laurentian rock. Surrounding territory unfitted for agric. and hence will undoubtedly remain uninhabited. Water has hardness of about 90 ppm., all carbonate, and color varies from 3 to 30 ppm. and avgs. about 10. Bact. count about 15 and coliform bacteria absent, although false pos. presumptives occasionally occur. Turbidity avgs. about 3 ppm., with max. of 6, latter largely due to plankton and decaying vegetable matter. Temp. varies from 34° to 79° F. Water conveyed to city by gravity, most passing through 2 open and 2 closed reservoirs with total capac. of 69.6 mil.gal. (U.S.). Chlorination practiced since '14. Tastes and odors troublesome since '37. $CuSO_4$ and activated C applied at entrance to reservoir system gave some relief but C dosage above 2.5 ppm. could not be employed without some C being carried into distr. system, causing complaints of "black" water. Break-point chlorination adopted in '41, T.O. number being reduced from 20 to 5. $CuSO_4$ applied continuously. Cl break-point varies from 1.15 to 2.16 ppm., most common value being 1.75. Cl applied at entrance to reservoir system and residual Cl content at pumps 0.2 ppm. Treatment effective against odors from all organisms encountered except *Rivularia*, although living *Melosira*, *Oscillatoria*, *Rotifera*, *Aphanizomenon* and other organisms noted in reservoirs while break-point chlorination being applied. Numerous complaints occur for first few days after treatment commenced, probably due to org. matter in mains being attacked. False o-t. test colors, believed due to vegetable matter, cause difficulties.—*R. E. Thompson.*

Failure of Chlorination and Appearance of Chlorophenol Taste and Odor in Ruhr Water Works. Z. Hyg. InfektKr. (Ger.) **123**: 6: 649 (May 16, '42). Chlorination of Ruhr water for drinking purposes commenced in '12. Bleach first used but later chlorine gas substituted. If phenol content of water rises above certain figure, chlorophenol taste and odor appear in water. During last few weeks of '38, tap sample gave high colony counts, *Esch. coli* present and chlorophenol taste and odor appreciable. Dose of chlorine was 0.

ppm. with no detectable residual chlorine. Dose stepped up, but not until dose of 0.5 ppm. reached did residual appear and bact. anal. become satisfactory. Taste complaints from consumers numerous. Reason for breakdown sudden severe frost with no prior heavy rainfall, temp. of river water falling to 0.2° C. and flow becoming very sluggish. Thus sewage effluents and trade wastes dild. but little and oxidation processes at standstill. General deterioration shown by anal., high ammonia and phenol contents and high colony counts including *Esch. coli*. Trouble confined almost entirely to lower Ruhr where many coke-ovens situated. Local authorities took steps to control trade wastes of these ovens and other factories, and worst bypassed into other streams not used for drinking water supplies. Normal high phenol content in Ruhr water, but table shows definite increase between '35 and '38. Powd. activated carbon employed to remove taste and odor and ammonia-chlorine process substituted for chlorine alone. In winters '39–'40 and '40–'41 floods before frosts and dose of chlorine required less than in '38–'39. Authors emphasize necessity of watching temp. of both air and water when controlling chlorination and stress importance of having chlorine cylinders in warmed rooms to prevent frosting and blocking of pipes and connections in app.—*B.H.*

Pollution of Drinking Water by Mineral Oils and Their Detection by Fluorescence With Ultra-Violet Light. J. HALSTRICK. Arch. Hyg. u. Bakt. (Ger.) **128**: 3: 155 ('42). Mineral oil imparts taste to water in concns. of 1 in 200,000 and odor in 1 in 400,000 parts. Odor of petrol more easily detected than that of crude oil, but latter tasted more quickly. Examn. of surface of sample of water not sensitive enough to detect minute quants. of mineral oil and may be necessary to exam. large quants. before drop found. Clear water shows slight bluish-white fluorescence with ultra-violet light. Refined mineral oils give blue color and crude oils yellowish brown shade. Dark room and dust-free atm. required for test. Many other substances impart fluorescence to water. By this test 1 in 20,000 parts petrol can be detected; therefore not as sensitive as detection by smell or taste. On other hand, crude oils can be detected up to 1 in 500,000 parts, improvement on taste and odor method.—*B.H.*

Why Do Earthy Smell and Taste Appear Occasionally in Water Basins? A. A. EGOROVA & B. L. ISACHENKO. Compt. Rend. (Fr.) **36**: 185 ('42). Earthy smell and taste result from life activity of actinomycetes. This micro-organism present to limited extent in water, but develops chiefly in upper 20 cm. of slit in bottom of reservoir; no correct judgment of no. of actinomycetes can be obtained by water sampling alone. Odor-forming products of life activity of actinomycetes pass into water (and retained by water) in varying amts., depending on adsorptive capac. of bottom deposit; over sandy bottoms water acquires noticeable odor and over clay bottom odor scarcely noticeable.—*C.A.*

Contribution on the Significance of Odor Tests in Water Examination. G. NACHTIGALL & E. GRILL. Arch. Hyg. u. Bakt. (Ger.) **129**: 1: 196 ('43). Quant. relationship shown between deg. of odor of water and oxygen absorbed figure. Improvement in purity of water through stages of purif. shown by loss of odor and reduced oxygen absorbed figures. Activated carbon shown to be effective agent for odor removal. Ortho-tolidine used to est. amt. of unreduced potassium permanganate in oxygen absorbed test.—*B.H.*

FILTRATION

Straining Plant for Water and Effluents. P. L. BOUCHER. Civ. Eng. (Br.) **38**: 262 (Dec. '43). In various indus. situations water supply may require purif. to fairly high std. without complete clarification. Cooling water typical example and water used for some kinds of washing. With some indus. effluents may be necessary to recover suspended solids. Straining formerly limited to elimn. of coarsest matter at intakes. Today automatic straining plant, including fine straining, available wherein great benefits in installation and operation may be obtained due to high flow ratings and low head losses. Straining media of woven wire cloth may be classified as coarse, with apertures down to $\frac{3}{16}''$; medium, with apertures between $\frac{1}{8}$ and $\frac{1}{64}''$; and fine, with apertures less than $\frac{1}{64}''$. Many different weaves available, such as square mesh—plain and twilled,

ribbon mesh, Hollander weave, braided weave, etc. (Table shows woven wire cloth with 40,000 apertures psi., giving aperture of 76 microns.) Fabrics available in copper, brass, phosphor bronze, monel metal and stainless steel. (Finest fabric mentioned, Micro-Fabric, British patented article, shows 122,500 apertures psi. with aperture of 20 microns.) Fine straining can be employed to reduce plankton content or to reduce load on filtration plant. Bacteria so small as to be beyond scope of ordinary straining. Rigid particles larger than apertures in straining medium bound to be elimd. Non-rigid particles of same dimensions can also be removed by correctly designed plant. Total straining eff. depends also on controlled matting effect by which large proportion of particles of sizes that would otherwise pass through apertures elimd. with larger debris. Effect increases in geometrical ratio the smaller the straining aperture. All fixed strainers have disadvantage that they have to be lifted for effective cleaning. Also risk of debris falling off and passing into outlet in concd. form. Such fixed strainers not to be compared with automatic, self-cleaning strainers of good design. Finest straining media cannot be used on them because of high rate of blockage. Two examples of automatic rotary strainers shown. These machines consist of revolving drum covered on periphery with requisite straining medium. Driving motor actuates wash water jets which cover drum surface as it rotates. Suspended particles trapped inside drum and carried up and dischgd. into waste trough fixed with its lip above water level. Wash water, especially for finest meshes, should be clean water, with pressure not more than 5 psi. Wash water consumption normally less than 1%. Rate of flow depends upon effective size of unit, concn. of suspended matter in water, straining medium in use, loss of head allowed and drum speed. Application of automatic rotary strainers has met with success, machines continuing to run without attention other than periodic lubrication.—*H. E. Babbitt.*

Open or Covered Slow Sand Filters? A. F. MEYER. Gas-u. Wasser. (Ger.) **85**: 478 ('42). Effects of algae in water to be treated on operation of slow sand filters discussed. Because algae on surface of sand liberate oxygen during day only, content of oxygen in effluent from filter shows diurnal variation. When content of oxygen in water low, aerobic bacteria, particularly in lower layers of filter, reduced in number. Under anaerobic conditions sulfur bacteria appear particularly in corners of filters, where mats of algae present; these bacteria oxidize hydrogen sulfide to sulfur. Ferrous sulfide formed from iron compds. in sand, which becomes black; color cannot be removed by washing sand but only by oxidation. Zooplankton can also cause anaerobic conditions in filter; to prevent such occurrence in open filters, microfauna should be regularly washed away. Filter sand may become clogged by sludge, detritus, dead phytoplankton, calcium carbonate and larvae of flies. Calcium carbonate, which cements sand grains and which is deposited from water, when carbon dioxide removed by algae, causes upper layers of sand to become impermeable. Some members of phytoplankton able to penetrate sand. Disadvantages of open sand filter are danger of poln. of water by birds and dust and warming of water by sun. Test made by N. V. Leidsche Duinwater Maatschappij in which exptl. filter provided with wooden cover, through which air, but not light, could enter. For first 240 days of expt. filter operated at rate of 1000 mm./hr.; chem. and bact. qual. of filtered water satisfactory. Filter runs longer than those of open filters which were operated at rates of 100 to 150 mm./hr. Later exptl. filter operated at rate of 500 mm./hr.; satisfactory effluent obtained whereas effluents from open filters frequently contained many bacteria, despite low rate of operation of filters. Temp. of water more equable in covered filter. Sand taken from surfaces of covered and open filters contained 1 g. and 46.8 g. of calcium carbonate per 100 g. of sand, resp. As result of this test large filter with surface area of 2000 sq.m. covered and operated satisfactorily at rate of 250 to 300 mm./hr. J. Smit, however, describes expts. made in Batavia with covered filter from which cover gradually removed. When filter completely open bact. count in 5 ml. of filtrate always less than 100 and *Esch. coli* absent, whereas when filter covered several hundred bacteria had often been found in 5 ml. From these results concluded that light had favorable effect. Smit also pointed out danger of insufficient supply of oxygen in covered filter. In expts. at water works at Voorburg, Holland, R. Hogendijk showed that longest filter runs and effluent of good qual. attained with open filters when weather cloudy. In spring when sunny weather

begins there is rapid clogging of open filters; also considers that more even temp. in covered filter an advantage.—*W.P.R.*

Cleaning of Slow Sand Filters. G. SATTLER. Gas-u. Wasser. (Ger.) **84**: 589 ('41). History of slow sand filters for treatment of water described. Purif. of water by filtration through slow sand filters brought about by decompn. of org. matter in water by micro-organisms on surface of sand. Bacteria in water also removed; pathogenic organisms more readily extracted than non-pathogenic bacteria. Bacteria in filtrate almost always non-pathogenic forms which live in lower layers of filter or in effluent pipe. Organisms on slow sand filters able to remove substances causing tastes in water which sometimes cannot be removed by active carbon or by addn. of coagulants followed by rapid sand filtration. Eff. of slow sand filter greatly influenced by temp. and by pH value. Number of organisms found during one day on surface of slow sand filter and at depths of 20 and 40 cm. below surface given. Observations made after filter in operation for more than 2500 hr. and when temp. of water 4.5° C. Very few organisms at depths of 20 and 40 cm. No organisms on surface of sand after filter had been washed. Chlorine destroys bactericidal action of organisms in slow sand filter. Organisms also affected by coagulants, by lime, by phytoplankton and by pieces of plants. Effect of prelim. treatment of water on filter runs in slow sand filters discussed. Filtration through coarse sand filter almost doubled filter run; treatment with coagulant followed by sedimentation for 4 hr. and by rapid filtration increased filter run from 3–4 wk. to about 6 mo. In past, slow sand filters cleaned by removing at intervals top few cm. of sand until about half sand had been removed. Since biol. processes take place on surface of sand, not necessary to have depth of sand greater than 40 to 50 cm. When filter requires cleaning usual method at present is to remove top 1 or 2 cm. of sand, which is washed and replaced. In filter cleaned in this way during operation for more than 8 yr. sand remained clean and loss in head very small. Advantage of breaking up lower layers of sand doubtful; better to remove, wash and replace 10 to 20 cm. of sand occasionally. Necessary occasionally to wash slime from gravel supporting sand.—*W.P.R.*

Filter Economy by the Use of H_2SO_4. S. R. J. COTTON. New Zealand J. Sci. Tech. (Br.) **26B**: 182 ('45). Description given of method used in Auckland, N.Z., water supply system to economize on use of imported $Al_2(SO_4)_3$. Water has very little turbidity. Coloring brownish yellow owing to decaying vegetation. Best results found at pH 5.2 obtained by depressing raw water pH to 5.8 with N H_2SO_4, and then addn. of 0.7 gpg. of com. $Al_2(SO_4)_3$. Savings in alum indicated by lab. expts. 42%. Plant-scale trials produced savings of 40% to 60%. When clay or suspended matter high use of H_2SO_4 effects no saving in alum. Costs given based on wartime prices in New Zealand, but satisfactory savings expected.—*C.A.*

Montreal Filtration Plant Extension. F. Y. DORRANCE. Wtr. & Sew. **83**: 5: 19 (May '45). Water supply of Greater Montreal drawn from St. Lawrence R. above Lachine Rapids and conveyed 5 mi. by conduit and open canal to filter plant. There are 2 intakes, 1 on shore and other extending 1200′ into river, each consisting of 2 pipes. In recent years, use of ever-increasing amts. of shore water, with its admixt. of highly colored Ottawa R. water, necessary. Planned to replace river intake with 6 new pipes of 300-mgd. total capac., extending 2000′ from shore. Original filter plant, designed for double filtration without coagulation and opened in '18, consisted of 16 prefilters and 16 slow sand filters, each with capac. of 3.2 mgd. Experience showed double filtration unnecessary and in '27–'28, 32 filters of same design as earlier prefilters added, all 48 units being then operated as rapid sand filters. Increased consumption since '40 necessitated operation much above rated capac. and contract now awarded for new battery of 16 filters, which will increase capac. from 150 to 200 mgd. In '44, avg. daily consumption 150.7 and max. 175.1 mil.gal. Each filter 50′ × 27.5′, divided into 2 by 2.5′ longitudinal central channel, sand area in each section being 1200 sq. ft. As in existing units, underdrains consist of c-i. manifolds and laterals, latter spaced on 6″ centers, with 2 bronze-bushed orifices in each 6″ of lateral. Combined air-water wash will be employed. Wash water troughs, 16 in each filter, about 14″ above sand. Filter will consist of 15″ gravel placed in 4 layers and 30″ sand, probably of effective size 0.45–0.55 mm., and uniformity coef. about 1.65. Extensions in-

clude new reservoir and conversion of slow sand filters into reservoir, both for filtered water. Work, estd. to cost $1,439,965 (excluding intake), will be completed in '46.—*R. E. Thompson.*

The Porous-Plate Underdrain System for Rapid Water Filters and Softeners. FRANK C. ROE. J. Missouri Water Sew. Conf. **15**: 4: 30 ('44). History and development of replacing all graded gravels plus lateral drains with relatively rigid and porous membrane presented. Advantages claimed include: uniform backwashing, protection of filter media, low constr. cost, low improvement or rehabilitation cost, low operation cost, advantageous use of surface wash equip., simple and uniform application of air wash. Design and constr. of gravity filters similar to usual filter design except that vertical dimensions reduced because of elimn. of graded gravel. Pressure filters and softeners more economically installed, since porous underdrain plates lower cost. Reason for this is that there is reduction in depth when graded gravel elimd. Detailed description of installation of porous underdrain systems and normal operation practice given. Recommendations based on actual installation experiences suggested. Conclusion: 8 yr. of successful operation indicates that it is adaptable to almost all rapid filtration problems.—*C.A.*

The Effect of Filtering Before the Determination of Residual Hardness in Boiler Feedwaters. OTTO HEUSE. Chem.-Ztg. (Ger.) **68**: 105 ('44). In detg. residual hardness by method of Boutron-Boudet-Seyb found that when water filtered pH value and hardness value affected, unless ashless filter paper used. With ordinary qual. filter paper, hardness increased from 0.20° to as much as 0.70°. Possible that error caused by use of poorer paper under war conditions.—*C.A.*

Properties of Filter Materials. GEORGE W. COLTMAN. Conf. of Swimming Pool Operators, under auspices of Ill. Dept. of Pub. Health, sponsored by Chicago Bd. of Education (Apr. 28, '43). Pool filter typical of Chicago Public Schools installation described. Silica sand or quartz should be free from clay, loam, vegetation, lime and org. matter and of uniform and proper size. Filter sand classified according to *effective size* and *uniformity coef.* Effective size of 0.4 mm. means that 90% of sand by wt. larger and 10% by wt. smaller than this dimension. Size variation of individual grains, however, materially affects filter eff. Deg. of variation called uniformity coef., obtained by finding size of particle coarser than 60% by wt. of sand, then size finer than 40%, and dividing that size by effective size. Thus, if 60% of sand with 0.4 mm. effective size passes 0.64-mm. screen, uniformity coef. is 0.64 ÷ 0.40, or 1.6, value extensively used for filters. *Anthracite coal* (*Anthrafilt*): During past 7 yr. specially prepd. anthracite coal filters installed in 1100 filtration plants, including about 100 swimming pools in U.S. Advantages: Larger particle size of filter anthracite, 0.7–0.73 mm. compared with 0.4–0.5 mm. effective size sand, will yield twice as long filter runs, higher filtration rates and less head loss. Supporting beds composed of anthracite sizes comparable to usual quartz sizes in conventional filters. Alum clarification of pool water described. Water should be sufficiently clear to see bottom guide lines at deep end. Turbid pool water often due to flocculation in pool instead of filter. Proper filter flocculation obtained by maintg. alky. from 7.4 to 7.8, checked daily. Filtration rate should be 3.5 gpm. per sq.ft. cross-section area of filter. Sufficient area should be provided to filter complete pool turnover in 7–8 hr. Circulating pump for 60,000 gal. pool should have 240-gpm. capac. To remove old filtrate and clogging material completely, backwash at rate of 15 gpm. per sq.ft. cross-section filter area. Effective backwash results in 50% filter expansion above normal size in properly designed filter, cleans thoroughly and prevents cementation. When pressure drop through filter exceeds 7 lb., backwash to waste, particularly with recirculated pool water from 6 to 15 min. until water in sight glass clear. Reversing operation, filter to waste until water similarly clear. This levels filter and fills channels from backwash. Some advocate air scrubbing when backwashing to clean quartz better and save wash water. Air applied under 3–5 psi. Air pipes, usually brass, placed in sand just above gravel layer, about 6″ on centers with ¼″ perforations approx. 6″ apart on each tube for air distr. From 3 to 5 cu.ft. of air per min. applied per sq.ft. of filter surface. With air, 8–10 gpm. of wash water per sq.ft. probably sufficient. In backwashing, open valves gradually to prevent gravel removal. Observe and control through sight glass.—*Ralph E. Noble.*